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Assessment of the southern Gulf of St. Lawrence Atlantic cod (*Gadus morhua*) stock of NAFO Div. 4T and 4Vn (November to April), March 2015

Douglas P. Swain, Luc Savoie, Sean P. Cox[1] and Éliane Aubry

Fisheries and Oceans Canada
Gulf Fisheries Centre
343 University Ave., Moncton (NB) E1C 9B6

[1]School of Resource and Environmental Management
Simon Fraser University, Burnaby (BC)

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The stock of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence (NAFO 4T and 4Vn (November to April)) supported landings averaging 30,000 t annually between 1917 and 1940 and 56,000 t annually between 1941 and 1992. The stock collapsed in the early 1990s due to high mortality. Moratoria on directed fishing for southern Gulf cod were put in place in 1994-1997, 2003 and since 2009. Reported by-catch in fisheries for other groundfish have averaged 127 t annually since 2009. During this period, estimated fishing mortality averaged 0.2% annually for cod aged 5-8 years and 0.7% for cod 9 years and older. Spawning stock biomass and abundance are at the lowest levels observed in the 65-year record and are declining. Estimated SSB has declined by about 70% from the already low level in 2000 and over 90% from the level in 1985. SSB is estimated to be about 40% of the limit reference point (LRP = 80,000 t) with essentially no chance of recovering to the LRP over the next five years, even with no fishing mortality. Although the 2011 year-class is estimated to be strong compared to other recent year-classes, it remains weak compared to those produced in the 1980s. SSB is projected to increase slightly in 2016 as the 2011 year-class continues to recruit to the mature stock. However, it is expected to decline from 2016 to 2019 as these fish suffer high natural mortality. With no fishing mortality, the probability that SSB in 2019 will be below the 2015 level is estimated to be 79%. The ongoing decline of this population is due to the high natural mortality of adult cod (i.e., ages 5 years and older). Natural mortality of about 18% annually is considered normal for adult cod. In this population, natural mortality of adults has increased over the past 35 years and is now estimated to be 50-60% annually. At this level of natural mortality the population is expected to continue to decline even with no fishing mortality. Predation by grey seals is considered to be a major cause of this mortality. Consequently, no recovery of this population is expected at the current high level of grey seal abundance in this ecosystem.

Évaluation du stock de la morue de l'Atlantique (*Gadus morhua*) du sud du golfe du Saint-Laurent, Divisons de l'OPANO 4T et 4Vn (novembre à avril), mars 2015.

RÉSUMÉ

Le stock de morue de l'Atlantique (*Gadus morhua*) du sud du golfe du Saint-Laurent (Divisions de l'OPAN 4T et 4Vn (novembre à avril)) a supporté des débarquements moyennant 30 000 tonnes annuellement entre 1917 et 1940 et 56 000 tonnes annuellement entre 1941 et 1992. Le stock s'est effondré au début des années 1990 dû à un taux de mortalité élevé. Un moratoire sur la pêche dirigée de la morue du sud du golfe a été mis en place en 1994 jusqu'en 1997, en 2003 et depuis 2009. Les prises accessoires reportées dans les autres pêches de poissons de fond ont totalisé une moyenne de 127 tonnes annuellement depuis 2009. Durant cette période, l'estimation de la mortalité par pêche moyennait 0,2% annuellement pour les morues âgées entre 5 et 8 ans et 0,7% pour les morues âgées de 9 ans et plus. La biomasse et l'abondance du stock reproducteur sont au plus bas niveau observé dans les 65 ans de données et continuent de baisser. L'estimation de la BSR a diminué d'environ 70% du déjà bas niveau de 2000 et de plus de 90% du niveau de 1985. La BSR a été estimé à environ 40% du point de référence limite (PRL= 80 000 t) avec aucune chance de rétablissement au PRL dans les prochains cinq ans, même sans mortalité par pêche. Malgré que la classe d'âge de 2011 ait été estimé forte par rapport aux récentes classes d'âges, elle demeure faible par rapport à celles produites dans les années 1980. La BSR est prévue d'augmenter légèrement en 2016 étant donné que la classe d'âge de 2011 continue de recruter dans le stock mature. Toutefois, elle est prévue de baisser de 2016 à 2019 puisque ces poissons vont affronter un haut taux de mortalité naturelle. Sans mortalité par pêche, la probabilité que la BSR, en 2019, soit en-dessous du niveau de 2015 est estimée à 79%. La diminution continue de cette population est due au taux de mortalité naturelle élevé chez la morue adulte de 5 ans et plus. Une mortalité naturelle annuelle d'environ 18% est considérée normale pour la morue adulte. Dans cette population, la mortalité naturelle a augmenté dans les derniers 35 ans et est maintenant estimée à 50-60% annuellement. À ce niveau de mortalité naturelle, la population est prévue de continuer à baisser même en l'absence de mortalité par pêche. La prédation par les phoques gris est considérée comme étant une cause majeure de cette mortalité. Conséquemment, aucun rétablissement de cette population n'est prévu vu le présent niveau d'abondance de phoques gris dans cet écosystème.

INTRODUCTION

The southern Gulf of St. Lawrence (sGSL) stock of Atlantic cod (*Gadus morhua*) overwinters in dense aggregations in relatively warm water along the southern slope of the Laurentian Channel in the sGSL and the neighbouring Cabot Strait area. In April and early May the stock migrates into the southern Gulf to spawn and feed, returning to the overwintering grounds in November. Consequently, the management unit for this stock consists of the Northwest Atlantic Fisheries Organization (NAFO) Division 4T as well as subdivision 4Vn from November to April (Fig. 1). This stock has been fished since the sixteenth century or earlier. Landings averaged over 47,000 t in the period from 1917 to1993, but the stock collapsed in the late 1980s and early 1990s. Following the stock collapse, the fishery was closed from September 1993 to May 1998. The fishery was reopened in 1998 as an index fishery with a total allowable catch (TAC) of 3,000 t. The TAC increased to 6,000 t from 1999 to 2002. The directed fishery was closed again in 2003 but was re-opened with a TAC of 3,000 t in 2004. The TAC was increased to 4,000 t in 2005 and reduced to 2,000 t in 2007.

A limit reference point (LRP) has been established for this stock, based on the spawning stock biomass (SSB) below which the probability of poor recruitment is high. The LRP, established in 2003 is estimated to be 80,000 t (Chouinard et al. 2003b).

The last full assessment of this stock was conducted in 2009, using data up to the end of 2008 (Swain et al. 2009). This assessment concluded that the stock had remained at low abundance since its collapse, with SSB at the beginning of 2009 at the lowest level observed in the 60-year record and well below the LRP. Lack of recovery was attributed to low productivity resulting from high and increasing natural mortality. Predation by grey seals was considered to be a significant component of this elevated natural mortality. Like previous assessments in 2006-2008, the 2009 assessment concluded that stock biomass was expected to decline over the short-term even without fishing. Subsequent to the assessment, the directed fishery was closed in 2009 and has remained closed since then (with a TAC of 300 t to cover by-catch in other groundfish fisheries, catch in a limited recreational fishery, catch for scientific purposes, and negotiated Aboriginal food, social and ceremonial catches).

In its 2003 assessment of Atlantic cod, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Maritimes Designatable Unit (DU) Special Concern. The sGSL stock was part of this DU. In April 2010, COSEWIC re-assessed Atlantic Cod and split the previous Maritimes DU into two populations, the Laurentian South DU and the Southern DU. The Laurentian South DU, which includes the sGSL cod stock, was designated Endangered, a higher risk category than Special Concern, due to a 90% decline in abundance over three generations. In response to the COSEWIC assessment, a recovery potential assessment (RPA) of the Laurentian South DU was conducted in 2011 based on data to the end of 2009 (DFO 2011; Swain et al. 2012). This RPA concluded that the sGSL cod stock was expected to continue to decline, even with no fishing, if productivity of the stock remained at its current low level. The main cause of low productivity was unusually high natural mortality of cod aged 5 years and older. Fishing mortality at the level in 2009 (following the closure of the cod-directed fishery; 1.4% annually for fully-recruited fish) was estimated to have a negligible impact on the probability of population survival, but fishing mortality at the level in 2007-2008 (10% annually for fully-recruited fish) decreased the probability of population survival under the prevailing low productivity conditions. The RPA concluded that the only additional action that could be taken to improve the chances for recovery of southern Gulf cod appeared to be action to reduce the rate of natural mortality on adult (5+) cod. Predation by grey seals was considered to account for a high proportion of this mortality.

This report describes the 2009-2014 fisheries for the southern Gulf of St. Lawrence cod stock and provides an assessment to Jan. 1 2015 of stock status based on research, sentinel and fishery data available to the end of 2014. Population models are fit to these data to provide estimates of population size and rates of fishing and natural mortality. Projections of population trends and rates of fishing and natural mortality over the 2015-2019 period are also provided, along with estimates of the uncertainty in these projections.

THE FISHERY

LANDINGS

Annual landings of sGSL cod averaged 30,000 t between 1917 and 1940 (Fig. 2). Landings increased following the introduction of otter-trawling in the 1940s, reaching a peak of 104,000 t in 1956 and averaging 56,000 t annually between 1941 and 1992. The first TAC was established at 63,000 t in 1974, declining to 15,000 t in 1977 (when 27,000 t were landed; Table 1). The TAC then increased to a peak of 67,000 t in 1984 and 1985. Landings also increased, averaging 61,000 t in the 1980s with a peak of 69,000 t in 1986. Landings began to decline in the early 1990s and the fishery was closed in September 1993 due to low cod abundance. During the first moratorium on directed cod fishing, reported landings of cod by-catch averaged 1,300 t annually. Following an "index" fishery in 1998 (3,000 t TAC), the directed cod fishery re-opened in 1999 with a TAC of 6,000 t. Annual landings averaged 5,800 t in 1999-2002. The cod fishery was closed a second time in 2003. Reported by-catch in 2003 was 289 t, considerably lower than by-catch during the first moratorium. The directed fishery re-opened again in 2004 but was closed in 2009. The TAC varied between 4,000 and 2,000 t during the re-opening. Reported landings averaged 2,264 t and were consistently below the TAC (averaging about 75% of the TAC). The directed cod-fishery has remained closed since 2009. Annual reported by-catch of cod landed in other groundfish fisheries averaged 127 t over the 2009-2014 period (Table 1).

Prior to the collapse of the stock and the closure of the directed fishery in 1993, catches by mobile gear (otter trawls and seines) dominated the landings reported since 1965 (Table 2). Catches by fixed gears have been a more important component of the landings since 1994, and have dominated the landings since the closure of the directed fishery in 2009 (Table 2).

By-catch of cod on trips targeting other species is summarized in Figure 3 for the 1997-2014 period (also see Table 3). The most important sources of by-catch were American plaice directed trips in the 1997-2004 period, witch flounder directed trips in the 2006-2009 period, and trips directing for Atlantic halibut since 2010. By-catch rates were highest on trips directing for Atlantic halibut, witch flounder and plaice (Fig. 4). Rates of cod by-catch have tended to decline over time.

During the moratorium since 2009, catches of cod by mobile gears have occurred primarily in May and June in the Cape Breton trough, along the slope of the Laurentian Channel and east of the Magdalen Islands (Figs. 5 and 6). Most of these catches were from the witch flounder fishery, with the redfish and yellowtail fisheries each contributing about 10%. Catches were sparser in July to October, and mostly occurred along the southern slope of the Laurentian Channel and in the Cape Breton Tough in the witch flounder and redfish fisheries (Fig. 6). Catches by fixed gears occurred from April to October, primarily in the Atlantic halibut fishery (though 20-30% of the trips landing cod were identified as cod-directed trips) (Figs. 7 and 8). Catches by fixed gears were highest in the Cape Breton Trough in April and June and near American Bank off the Gaspe coast in July and August. Catches also occurred off Miscou, along the north coast of PEI and around the Magdalen Islands in July to October. The sentinel programs contributed 15-25% of the landings during the moratorium, with 80-90% of the sentinel landings made by the longline program (Appendix A; Tables A1-A6). Additional details related to the distribution of landings between months and gears are available in Appendix A for the moratorium period.

A recreational fishery also occurred during the moratorium, with openings of five weeks or less. This fishery had a daily bag limit of five cod and/or white hake. Data on catches in this fishery are not available. They were estimated to be 5.5 t in 2008, and are likely to be lower now. Charter boats fishing with rod and reel were also permitted to operate in LFA 24 and LFA 26a (groundfish management zones 4T2b and 4T8, Fig. 9) between July 1 and September 15 under a licence to fish for educational purposes. This fishery had a limit of 20 cod per trip to a maximum of 60 cod per calendar day. Based on data from observed trips, cod catches were very low, averaging 1.3 kg per trip. The total cod catch by charter boats in 2014 was 13.2 t, with 2.8 t landed and 10.4 t released.

FISHERY CATCH-AT-AGE

Age Determination

Consistency of age determinations was verified by regular blind tests against a reference otolith collection. Tests were performed prior to the beginning of ageing and after every 500 – 1,000 fish had been aged. Each test consisted of readings of approximately 120 otoliths. The level of agreement with the reference collection varied between 85-93% with no bias detected. The minimum acceptable level of agreement is 75%. Based on these results, the consistency of age readings was considered to be adequate.

Catch-at-age

Calculation of the catch-at-age for 2009-2014 is described in Appendix B. In most years there were four age-length keys: commercial mobile gear (usually April or May to October or November), commercial fixed gears (usually April to October or November), sentinel longline (July to November) and mobile sentinel (August). In some years, there were two keys for commercial mobile or sentinel longline, each covering shorter time periods. The catch-at-age for the unsampled catch (0.01-3.6 t depending on year) was calculated by prorating the catch-at-age by the ratio of total to sampled commercial landings.

Mean weights-at-age in the commercial catch were calculated for each year based on the length distribution in the samples of the catch in that year and the parameters of the length-weight relationship in that year (estimated using data from the September RV survey). The numbers landed, mean weights-at-age and mean lengths-at-age are given in Appendix B Tables 1 to 4, for each age-length key in 2009-2014.

The most common age in the fishery catch was either 5, 6 or 7 years old in most years prior to the stock collapse and 7 years old in most years since the collapse (Table 4). Weight-at-age in the catch declined between the late 1970s and the mid to late 1980s (Table 5). Catch weight-at-age increased slightly in the 1990s (reflecting the increase in the proportion of the landings taken by fixed gears), decreased slightly in the mid to late 2000s and has been relatively high in recent years (perhaps reflecting the importance of the Atlantic halibut fishery in recent by-catch of cod).

ABUNDANCE INDICATORS

DFO BOTTOM-TRAWL SURVEY

Background

A research vessel (RV) survey of the southern Gulf of St. Lawrence has been conducted each September since 1971. This survey follows a stratified-random design, with stratification based on depth and geographic area (Fig. 10). Fishing was by the *E.E. Prince* using a Yankee 36 trawl from 1971 to 1985, by the *Lady Hammond* using a Western IIA trawl from 1985 to 1991, by the *CCGS Alfred Needler* using a Western IIA trawl from 1992 to 2005 (except 2003), and by the *CCGS Teleost* using a Western IIA trawl since 2004. When gear and/or vessels were changed, comparative fishing experiments were conducted and conversion factors have been applied where necessary (Benoît and Swain 2003; Benoît 2006) to maintain the consistency of the time series.

In 2003, the regular survey vessel, the *CCGS Alfred Needler*, was disabled by a fire and the survey was conducted by the *CCGS Wilfred Templeman*. However, the start of the survey was delayed, and only 83 fishing stations were surveyed. Three strata (402, 425 and 436 – see Fig. 10) were sampled with only one fishing set and two strata (438 and 439) were missed altogether. Estimates for the missed strata were obtained using a general linear model (Chouinard et al. 2005a). Despite the correction for missed strata, numbers per tow for 2003 (Table 6) were the lowest in the time-series (prior to the 2010-2012 surveys). Because of the difficulties with the survey, the index for 2003 is considered anomalous and is not used to fit population models (see below).

In 2004 and 2005, the survey was conducted by two vessels, the *CCGS Teleost* and *CCGS Alfred Needler*, both using the Western IIA trawl. During both surveys, comparative fishing experiments were conducted, with the two vessels trawling side-by-side. These experiments showed no significant difference in the catchability of cod between the two vessels (Benoît 2006). Stratified abundance estimates for cod for 2004 and 2005 were calculated by averaging catches of the two vessels that occurred at the same location.

Abundance and biomass indices

The survey catch rates indicate that the stock was at a low level in the early to mid-1970s, increasing rapidly in the late 1970s to relatively high levels of abundance and biomass in the early to mid-1980s (Fig. 11). Abundance and biomass decreased rapidly in the late 1980s and early 1990s, and the stock has been at a low level since then.

Catch rates of cod at pre-commercial sizes (< 42 cm; corresponding roughly to juvenile cod) generally declined slowly from 1992 to 2012 (Fig. 12a, 12b). This declining trend was interrupted by relatively high catch rates of small cod in 2002, 2004 and 2009. However, uncertainty in the indices in these years was high, and these relatively high catch rates of small fish were not reflected in increased catch rates of large fish in subsequent years. Catch rates of small cod were again relatively high in 2013 and 2014. However, uncertainty in these indices is high, and they remain well below the catch rates observed in the 1980s, particularly in terms of biomass.

Catch rates of cod at commercial sizes (≥ 42 cm; corresponding roughly to adult cod) recovered slightly in the early 1990s but declined substantially between 2002 and 2012 (Fig. 12c, 12d). Mean catch rates at these sizes declined by nearly 90% from the average level in the 1995-2002 surveys to the level in the 2011 and 2012 surveys. Catch rates increased marginally in the 2013 and 2014 surveys but catch rates in the 2014 survey remained only 80% of the 1995-2002 level. In conclusion, catch rates in the RV survey indicate that commercial-sized cod are at record-low levels of abundance and biomass has declined severely from the already low levels observed in the late 1990s and early 2000s.

Geographic distribution

In the 2002 – 2006 surveys, catch rates of cod tended to be highest in a band extending from Miscou, along the northern coast of PEI, into the Cape Breton Trough and along the southern slope of the Laurentian Channel between Cape Breton and the Magdalen Islands (Fig. 13). Since then, there has been a progressive shift in distribution with catch rates increasing in the vicinity of American Bank off the Gaspe coast and decreasing in the area west and north of PEI, though catches remained relatively high in some tows off the north coast of PEI.

Striking shifts in cod distribution are evident over the long term (Fig. 14). In the 1970s, cod densities were highest in western regions of the sGSL, including the area between PEI and Miramichi Bay. As cod abundance increased to a high level in the 1980s, distribution expanded, with relatively high densities throughout the Magdalen Shallows. As abundance declined to a low level in the 1990s, distribution contracted out of the central Magdalen Shallows, with densities highest in a band extending from Miscou, and along the northern coast of PEI, into the Cape Breton Trough and along the southern slope of the Laurentian Channel. Since the 1990s, cod distribution has progressively shifted out of inshore areas to the west and east of PEI and in Chaleur Bay, areas where cod abundance was relatively high during the low abundance period in the 1970s. Concurrent with this shift out of inshore waters, densities increased in deeper water along the southern slope of the Laurentian Channel. In the most recent period (2010-2014), cod densities were low in most areas of the sGSL and relatively high in a band extending from American Bank and along the southern slope of the Laurentian Channel to the Cape Breton Trough. The progressive shift in cod distribution out of shallow inshore areas throughout the 1990s and 2000s is thought to be related to increased risk of predation by grey seals in these areas (Swain et al. 2015).

Length distribution

In addition to a large decline in abundance, length distributions of cod caught in the RV surveys indicate a disproportionate loss of large individuals in recent years (Fig. 15). Throughout the 1980s, 1990s and early 2000s, cod above the minimum commercial length (43 cm) comprised a high proportion of the survey catch. This proportion has declined substantially in recent years. In the 2006-2008 surveys, 48% of the cod caught were above 43 cm in length. This proportion declined to 18% in the 2012 survey and 13% in the 2013 and 2014 surveys. The decline between 2012 and 2013 reflects the relatively high catches of small cod in 2013 and 2014. That is, the decline in the proportion of commercial-sized fish after 2012 reflects increased catch rates of smaller fish, not decreased catch rates of commercial-sized fish.

Age composition

Catch rates in the RV survey indicate a substantial decline in the abundance of older cod (ages 6+ years) in the last 4 or 5 years (Table 6; Fig. 16). In contrast, catch rates of 3-year-old cod in 2013 and 2014 were the highest seen since 1990. Catch rates were also relatively high for 2-year-old cod in 2013.

Size-at-age and condition

The predicted weight in September of an Atlantic cod of 45 cm length, used as an index of condition, was based on the annual length-weight relationships estimated from the survey data.

Estimated condition was relatively high in the early to mid-1970s, declining to relatively low values in the early to mid-1980s (Fig. 17). Condition recovered to average levels throughout the 1990s and early 2000s but declined to a lower level in recent years.

Mean length and mean weight-at-age declined from the late 1970s to the mid to late 1980s (Tables 7 and 8; Fig. 18). Size-at-age has remained stable at a low level since then.

MOBILE SENTINEL SURVEY

The mobile sentinel survey, conducted each August since 2003, is a stratified-random bottom-trawl survey using the same stratification scheme as the RV survey. Each year the survey is conducted by four commercial fishing vessels, each using the same standardized otter trawl (the 300 Star Balloon) and standardized fishing protocols (see Savoie 2012 for details). Each year, the four vessels fished in overlapping areas. Each vessel was assigned random fishing locations in most of the survey strata.

There have been six vessel changes between 2003 and 2014: vessel 17790 replaced 11873 in 2004, 11870 replaced 17354 in 2006, 64796 replaced 5688 in 2007, 100278 replaced 64796 in 2010, 151573 replaced 151347 in 2014, and 11502 replaced 17790 in 2014. In order to account for these vessel changes, the relative fishing efficiency (*E*) of each vessel for cod was estimated using a generalized linear model assuming a Poisson error distribution with overdispersion. Analyses were conducted using the GENMOD procedure of SAS (SAS Institute Inc., 1989). Explanatory variables in the model are year, stratum and vessel (see Poirier and Currie 2007 for further details). The model is of the form:

$$E(Y_{ijkl}) = \mu_{ijkl} = \exp(\beta_0 + \beta_{1i} + \beta_{2j} + \beta_{3k}) \qquad (1)$$

$$\mathrm{Var}(Y_{ijkl}) = \Phi\ \mu_{ijkl} \qquad (2)$$

where Y_{ijkl} is the catch in tow *l* in year *i* and stratum *j* by vessel *k*, β_0 is the intercept parameter, β_1 is a vector of year effect parameters, β_2 is a vector of stratum effect parameters, β_3 is a vector of vessel effect parameters, and Φ is a parameter for extra Poisson variation. The model is fit using a quasi-likelihood approach.

Previous studies have indicated that standard significance tests for Poisson regression may be too liberal when applied to catch rate data (Casey and Myers 1998; Benoît and Swain 2003). Thus, randomisation tests were conducted to verify the significance of vessel effects. For each iteration of a randomisation trial, each catch was assigned randomly to one of the vessels fishing in the stratum in which that catch was made. A thousand iterations were conducted to assess the significance of vessel effects.

When vessel effects were determined to be significant, further hypothesis tests were performed using the original model to determine which vessels could be grouped together under the same relative fishing coefficient. Coefficients were then recalculated for both numbers and weights for each vessel group and subsequently used in analyses requiring standardization. The reference vessel was chosen to be the *Miss Lamèque* (vessel 151347), as it is the vessel with the longest history in the program (2003-2013). This procedure was applied to the 2003 to 2014 data set.

All model effects were highly significant according to analysis of deviance (Table 9), and the randomization test confirmed that there were significant vessel effects ($P = 0.006$). The estimated fishing efficiency coefficients are shown for each vessel in Figure 19. Estimated efficiencies of vessels 5688 and 11873 did not differ from the reference vessel (151347), and the three vessels were grouped together for the final analysis. Efficiencies of vessels 64796 and 100278 were significantly lower than that of the reference vessel, and these two vessels were grouped together. Efficiencies of vessels 11870, 17354 and 17790 were significantly higher than that of the reference vessel, and these three vessels were grouped together (though an alternate choice would be to group 17790 with the reference vessel). Efficiencies of the two new vessels in 2014 (11502 and 151573) were estimated to be much higher than those of the other vessels, though the uncertainty in these estimates was very high. For this analysis separate fishing efficiencies were estimated for each of these vessels, though this may change as additional data accumulates. Fishing efficiencies relative to the reference vessel were estimated to be 1.49 (weight/tow) and 1.64 (numbers/tow) for the 11870, 17354 and 17790 vessel group, 0.55 (weight) and 0.46 (numbers) for vessels 64796 and 100278, 3.63 (weight) and 5.68 (numbers) for vessel 11502, and 2.75 (weight) and 3.43 (numbers) for vessel 151573.

The mobile sentinel indices showed similar trends with and without adjustment for differences in fishing efficiency between vessels, except in 2014 (Fig. 20). The abundance and biomass indices showed a declining trend from 2003 to 2013, with the 2003 and 2004 indices the highest in the time series and the 2012 and 2013 indices the lowest in the time series, about 20% of the 2003-2004 level. Without adjustment, the abundance and biomass indices in 2014 are at the 2003-2004 level, but uncertainty in these indices is extreme. With adjustment for the differences in fishing efficiency, the indices are at a low level in 2014.

The geographic distributions of catches in the sentinel survey in August (Fig. 21) are generally similar to those in the RV survey in September (Fig. 13), except that relative densities tend to be somewhat greater near American Bank and lower north of PEI in the sentinel survey, particularly early in the time series. Catches in the sentinel survey show the same shift out of shallow inshore areas that is observed in the RV survey.

Like the RV survey, the proportion of cod above the minimum commercial size of 43 cm has decreased in the sentinel catches over time (Fig. 22). In 2003, 36% of the sentinel catch consisted of commercial-sized cod, declining to 5% in 2013. In 2014, commercial-sized cod comprised 21% of the sentinel survey catch.

Cod aged 3-5 years account for about 60% of the mobile sentinel catch (Table 10). Unlike in the RV survey, catches of 2 and 3 year old cod were not unusually high in the 2014 sentinel survey; in 2014, catch rates of 2 and 3-year-old cod were 20% and 47% of the survey average. No trends in length or weight-at-age are evident over the 2003-2014 time series of the mobile sentinel survey (Table 10).

LONGLINE SENTINEL PROGRAM

Sentinel longlines have been fished with consistent protocols since 1996. Each participating vessel is required to fish at two traditional fishing areas selected by the participating fishermen (or their association). The fishing locations are 2.5 miles in radius and at least 5 miles apart. Once the locations were determined, they remained constant throughout the fishing season (Note: new sites have been incorporated each year since 1996 and several have been discontinued). Each vessel fished it's gear a maximum of 18 times during the fishing season, with a maximum frequency of twice per week. The fishing days could be consecutive within each 7-day period. A maximum of 1,250 hooks (size 12 circle, 1 fathom apart) were set at each site. Soak time was a minimum of 4-6 hours and a maximum of 24 hours. On each fishing trip, detailed information was collected by fisheries observers on the catch composition and length frequency, as well as material for age determination.

Catch rates were standardized using a multiplicative analysis (Robson 1966; Gavaris 1980) with the SAS GLM procedure (SAS Institute Inc. 1989). The approach was similar to that used by Chouinard et al. (2000). Observations of catch and effort for each individual site were aggregated on a monthly basis. Data cells (eg. monthly aggregates) where effort was less than one complete fishing day were eliminated from the analysis. Analyses were restricted to the

July-October period, except for the Cape Breton Trough sites which were not fished in July. Sites that have been fished in at least four years were included in the analysis. There are currently 36 fishing sites in the sentinel longline program, distributed throughout inshore areas of the southern Gulf (Fig. 23). Catch rate data were $\log_e$-transformed after adding a constant (1) to each catch rate to deal with zero catch rates.

The model was as follows:

$$\ln A_{ijk} = B_0 + B_1 I + B_2 J + B_3 K + \varepsilon \qquad (3)$$

where A_{ijk} is the catch rate (+1) for year i during month j at site k, I is a matrix of 0 and 1 indicating year, J is a matrix of 0 and 1 indicating month, and K is a matrix of 0 and 1 indicating site.

Results of the catch rate standardization are shown in Table 11. The model accounted for 62% of the variation in catch rates aggregated by site, month and year. Effects of site, month and year were all highly significant ($P<0.0005$).

Monthly catch rates by province prior to standardization are shown in Figure 24. Historically, average catch rates were highest off PEI and New Brunswick in September and off Nova Scotia in October, and lowest off Gaspe. In contrast, average catch rates were relatively low off PEI and relatively high off Gaspe in 2014.

Standardized catch rates declined steadily between 2004 and 2011 (Fig. 25). The catch rate in 2011 was 19% of the 1995-2004 average. Catch rates remained near this low level in 2012-2014, averaging 26% of the 1995-2004 level. Declines in the sentinel longline catch rates are substantially greater for older ages (Table 12).

POPULATION ANALYSES

SURVEY-BASED ANALYSES

Relative year-class strength

Catch rates at ages 2 and 3 years in the RV and mobile sentinel surveys were analyzed with a multiplicative model to obtain estimates of relative year-class abundance. Ages 2 and 3 were used in the analysis to minimize effects of fishery exploitation on year-class abundance. The model was:

$$\log_e A_{ijs} = \beta_0 + \beta_i + \beta_j + \beta_s + \beta_{is} + \varepsilon \qquad (4)$$

where A_{ijs} is the survey index at age i and year-class j in survey s, β_i is a parameter for the effect of age, β_j is a vector of parameters for the effect of year-class, β_S is a parameter for the survey effect, and β_{iS} is a parameter for the interaction between survey and age. The interaction term was included to account for differences in recruitment at age to the two surveys.

The model accounted for 85% of the variation in log catch rates. Estimated year-class strength was relatively low for year-classes produced in the late 1960s and early 1970s and high for those produced from the mid-1970s to the late 1980s (Fig. 26). Year-class strength declined in the late 1980s and early 1990s, and fluctuated at a low level throughout the 1990s. The 2001 and 2002 year-classes were the strongest year-classes produced since the early 1990s, but remained weak relative to those produced from the mid-1970s to late 1980s. The 2003 year-class was estimated to be the lowest in the time series. Strength was estimated to be low for the

2009 year-class and relatively high for the 2011 year-class, though not as high as the 2001 year-class.

Mortality estimates

Trends in fishing mortality can be described using a relative index obtained from the ratio of catch-at-age divided by the RV population estimates at age (Sinclair 1998). Provided that the survey index is taken close to when the population is at its average abundance for the year, these relative fishing mortality (F_r) estimates are not affected by changes in natural mortality.

Relative fishing mortalities were high in the early 1970s, followed by a decline in the late 1970s (Fig. 27) as stock abundance increased (Fig. 12). F_r was stable throughout of the 1980s, but increased beginning in about 1989 to a peak in 1992. With the closure of the cod fishery in September 1993, F_r dropped to the lowest level previously seen, and with the continued fishery closure, F_r declined further in 1994 and remained low until a limited commercial fishery was opened in 1999. This fishery, with a TAC of 6,000 t, resulted in an increase in F_r well above the very low levels during the moratorium. With the closure of the cod-directed fishery in 2003, F_r returned to levels near zero. The cod-directed fishery again re-opened in 2004 with a TAC of 3,000 t, increasing to 4,000 t in 2005 and 2006. This fishery resulted in levels of F_r above the levels observed in 1993 when the fishery was first closed. The TAC was reduced in 2007, resulting in a reduction in F_r. The directed fishery was again closed in 2009, and has remained closed since then. F_r has been near zero during the current moratorium.

Estimates of the instantaneous rate of total mortality (Z) were derived from the catch rates at age in the September RV and the August sentinel surveys. Estimates were obtained using analysis of covariance as described in Sinclair (2001). Analyses were conducted in 5-yr blocks, with $\log_e$ catch rate as the dependent variable, age as the covariate and year-class included as a factor (to control for variation in year-class strength). Ages 7-11 were used. These ages appear to be fully recruited to these surveys. Time series of relative fishing mortality for ages 7-11 averaged over the same 5-yr blocks, are compared to the time series of Z estimates. Z is an instantaneous rate whereas F_r is an annual rate.

Based on the RV survey catch rates at age, Z increased sharply in the late 1980s, peaking at values greater than 1 and then dropped sharply with the closure of the fishery in 1993 (Fig. 28). These changes in Z reflected changes in fishing mortality. However, Z remained high following the closure of the fishery in 1993. Based on the RV data, estimated Z was about 0.55 during the mid to late 1990s, increasing to values between 0.69 and 1.16 (mean 0.83) in the 2000s. The August sentinel trawl data also indicated high Z in the 2000s, with estimated values between 0.64 and 0.97 (mean 0.82).

The estimates of Z during the fishing moratorium in 1994-1997 indicate that the instantaneous rate of natural mortality (M) was 0.5 or higher during this period. Estimated Z in 1994-1997 was 0.56 (95% CI 0.49 - 0.63). Relative fishing mortality (ages 7-11 years) during this period averaged 0.020. Thus, even assuming that catchability to the survey is 100%, the contribution of estimated fishing mortality to Z during this period is negligible. It might be hypothesized that high Z during this period reflects high levels of unreported catch rather than high M. However, even if fishery removals were three to four times the reported landings during the moratorium (which is very unlikely), M would need to be 0.4 or higher to account for the estimated Z. The very high Z estimates throughout the 2000s indicate natural mortality has increased to even higher levels, though the uncertainty in the recent estimates is high due to possible year effects in the survey data.

Earlier studies obtained estimates for M of southern Gulf cod using data from the 1970s and earlier (Dickie 1963; Beverton 1965; Myers and Doyle 1983). The estimates from these studies vary between 0.07 and 0.1-0.2. Our estimates of Z and F_r indicate that there have been large increases in *M* between the 1970s and the 1990s.

Age at maturity

Earlier assessments of sGSL cod have assumed that age at maturity has not varied over time (e.g., Swain et al. 2009). In these assessments, it was assumed that the percent mature was 12.1% for 3-year-olds, 36.8% for 4-year-olds, 72.1% for 5-year-olds, 90.5% for 6-year-olds, 97.4% for 7-year-olds, and 100% for older fish. However, recent research has indicated that age and size at maturation of sGSL cod decreased sharply over time in cohorts produced in the 1950s and 1960s, but has changed little since then (Swain 2011; see Fig. 29). When mortality is high, fitness tends to be greater for individuals that mature early. The decline in age and size at maturity between the late 1950s and the early 1970s is thought to reflect an evolutionary response to high fishing mortality in the 1950s and 1960s. The continued early maturation following the sharp reduction in fishing mortality in the early 1990s is thought to reflect the current high natural mortality.

In this assessment, changes in age at maturity have been taken into account when calculating spawning stock biomass (SSB). The maturity ogives used in this calculation are given in Table 13. Because changes in maturation have now been taken into account, SSB no longer represents a consistent measure of the biomass of large individuals (e.g., commercial-sized cod) in the population. For example, the biomass of commercial sized cod was relatively high in the 1950s (see below). However, many of these cod were not mature and are not included in SSB. Thus 5+ biomass is presented in addition to SSB in the analyses below in order to provide a consistent measure of variation in population biomass at commercial sizes.

POPULATION MODELS

Methods

Two types of age-structured population models were fit to the sGSL cod data: Virtual Population Analysis (VPA) and Statistical Catch at Age (SCA). All models were implemented in AD Model Builder (Fournier et al. 2011). The main differences between VPA and SCA are as follows:

- VPA assumes that the fishery catch-at-age is known without error; SCA assumes that there is observation error in the proportions at age in the fishery catches.
- VPA fits to the abundance indices at age and assumes that indices at different ages in the same year are independent. SCA fits to the age-aggregated biomass indices separately from the proportions at age in the fishery and survey catches; this accounts for the lack of independence between catches at different ages in the same year.
- VPA is backward projecting from abundance at age in the terminal (most recent) year; terminal abundances at age are parameters estimated in the model. SCA is forward projecting from abundance at age in the first year and at the first age in all years; these are estimated in the model, either as parameters (the approach used here) or by fitting a stock-recruit relationship.

Models extended from 1950 to 2014 and from age 2 to ages 12+ (i.e., 12 years and older). Data inputs for VPA models were fishery catches at ages 2 to 12+ (in numbers), trawlable abundances at ages 2 to 11 in the RV survey (1971-2002, 2004-2014) and in the mobile sentinel (MS) survey (2003-2014), and standardized mean catch rates at ages 5-11 in the longline sentinel program (LL) (1995-2014). Data inputs for SCA models were total annual fishery catch (tonnes), age-aggregated (ages 2-11) trawlable biomass in the RV and MS surveys, age-aggregated standardized catch rates (kg per 1000 hooks) for ages 5-11 in the sentinel longline program and proportions at age in the fishery (ages 2-12+), RV and MS catches (ages 2-11) and in the longline program (ages 5-11).

Fu and Quinn (2000) and Jiao et al. (2012) demonstrated that it is possible to estimate time-varying *M* using length- or age-structured population models. In both VPA and SCA models, independent time series of the instantaneous rate of natural mortality (*M*) were estimated for three age groups: ages 2-4, 5-8 and 9+. These time series were estimated as random walks:

$$M_{j,1} = Minit_j \tag{5}$$

$$M_{j,y} = M_{j,y-1} e^{Mdev_{j,y}} \text{ if y>1971} \tag{6}$$

$$Mdev_{j,y} \sim \text{Normal}(0,0.05^2) \tag{7}$$

where $Minit_j$ is *M* in year 1 (1950) and $Minit_j$ and $Mdev_{j,y}$ are parameters estimated by the model. *M*dev was assumed to be normally distributed with a mean of 0 and a standard deviation set at 0.05. The random walk started in 1972, the second year in the time series with abundance index data. Priors were supplied for $Minit_j$. These priors were normally distributed with means of 0.65, 0.15 and 0.15 for cod aged 2-4, 5-8 and 9+ years, respectively. For ages 5+, prior means were based on empirical estimates of the *M* of sGSL cod in the 1950s and 1960s (see above). The prior mean for ages 2-4 was selected based on empirical relationships between *M* and length and growth characteristics of marine fishes (Gislason et al. 2010). Standard deviations for the *M* priors were set at 0.1, 0.05 and 0.05 for cod aged 2-4, 5-8 and 9+ years in the VPA model and 0.05 for all age groups in the SCA model. Simulation tests of VPA models for SGSL cod indicate that they result in reliable conclusions about changes in *M* of cod (Swain and Benoit 2015). While the sGSL cod data are informative regarding the level and trend in *M* of 5+ cod, they provide little information on the level of *M* at ages 2-4 years (Swain 2012; Swain and Benoit 2015; supplementary information). Thus, the estimates of *M* at ages 2-4 years are strongly influenced by the prior for *M*. However, the estimates for age 2-4 *M* have no impact on the estimates of mortality and abundance at older ages (Swain 2011b; Swain and Benoit 2015; supplementary information).

Fishery selectivity in the SCA model and selectivity in the surveys and LL program in both models were assumed to be a logistic function of age. For the fishery, separate functions were fit in 1950-1959, 1960-1975, 1976-1993 and 1994-2014. These time periods were chosen based on an examination of partial recruitment curves produced by the VPA.

In the SCA model, abundance of age-2 recruits was modeled based on either average recruitment (R) or average recruitment rate (*R*rate), with a random walk in deviations around the average value in both cases. The recruitment rate deviations were assumed to be auto-correlated. Differences between the results of the two approaches were negligible, and only the recruitment rate approach is presented here.

In VPA models, parameters were estimated by minimizing an objective function with the following components:

- a component for the discrepancy between observed and predicted values of the abundance indices at age, which were assumed to be log-normally distributed,
- a normal prior for the log *M* deviations, and
- a normal prior for the initial values of *M*.

The objective function for the SCA models included the following components:

- discrepancies between observed and predicted values of the age-aggregated biomass indices for the RV and MS surveys and the LL program,
- discrepancies between observed and predicted proportions at age in the fishery, RV, MS and LL catches,
- a normal prior for the log *M* deviations,
- a normal prior for the initial values of *M*, and
- a normal prior for the log recruitment deviations.

The standard deviation (SD) of the log recruitment deviations is not jointly estimable with the SD of the *M* deviations and was therefore set to 0.5. The proportions at age were assumed to follow a multivariate logistic distribution, which estimates data variances. Alternative statistical models, such as the multinomial distribution, require pre-specified effective sample sizes, which can have a large impact on model results. Approximate 95% confidence intervals were obtained for quantities estimated by both types of models based on 200,000 MCMC samples, with every 40th sample saved.

RESULTS

Model fit

The fits to the age-aggregated biomass indices was good for both VPA and SCA models, though the sum of squared residuals between observed and predicted log indices was greater for the SCA model than for the VPA model (Fig. 30). Any lack of fit between observed and predicted values tended to be similar between the two models (e.g., the observed RV indices in 2011 and 2012 were below and the 2013 observation was above the predicted values from both models, Fig. 30). The main difference in fits was a greater tendency for predictions by the SCA model to be above the observed RV indices in the 1970s and below the RV indices in the 1980s.

Patterns in the residuals between observed and predicted log numbers at age were similar between the two models (Fig. 31). For both models, these residuals indicated year effects in the same years. There was a greater tendency for SCA model residuals to be high in the 1970s and low in the 1980s. Residual patterns tended to be most similar over the past 15 to 20 years. Summed over all indices, the sum of squared residuals was similar between the two models (143.5 for SCA and 148.5 for VPA).

Both models also provided a good fit to the observed trends in abundance by age group (Fig. 32). Predicted abundance by the SCA model tended to be lower than observed values for 5-8 year olds in the 1980s and higher for 2-4 year olds in the 1990s and 2000s.

Residuals between the proportions at age observed in the fishery catch and in the indices and the proportions predicted by the SCA model are shown in Figures 33 and 34. Some "blocking" of residuals are evident but the patterns are not unacceptably extreme.

Model estimates

Retrospective patterns in model estimates of biomass and *F* were negligible for both SCA and VPA (Fig. 35). For both models, there were some changes in recent estimates of *M* as additional years of data were added, but the direction of change was variable and general conclusions about *M* (e.g., whether it was at a high level) were not affected.

In both VPA and SCA, cod were estimated to be fully recruited to the RV and mobile sentinel surveys at about age 6 but not until age 11 or older for the sentinel longline program (Fig. 36). With the indices at the scale of trawlable abundance, fully-recruited catchability was estimated to be 0.91 for the RV survey and 0.82 for the mobile sentinel survey in VPA, and 0.73 and 0.65 in SCA. Considering that the calculation of trawlable abundance does not take herding by the doors into account, these estimates are considered plausible. Selectivity by the fishery was estimated to be lower at younger ages since 1994 compared to earlier years. This is consistent with the increased importance of fixed gears, in particular longlines, in the catch since 1993.

Estimated trends in biomass were similar between the two models (Fig. 37, Table 14). Estimated 5+ biomass was at a high level in the 1950s, declining to a low level in the mid-1970s. Biomass returned to a high level in the 1980s and a low but stable level from the early 1990s to the early 2000s. Biomass then began to decline further, reaching the lowest level in the 65-year record in recent years. Trends were similar for SSB, except that SSB was considerably lower than 5+ biomass in the 1950s and 1960s due to the later maturation of cod at that time. Biomass estimated by SCA tended to be greater than that estimated by VPA, but biomass estimates by the two models converged to the same level in recent years.

Based on VPA, the estimated SSB was 25,540 t (95% CI: 20,420-30,880) in 2014 and 31,000 t (22,000-42,400) at the start of 2015. This represents a 75% decline between 2000 and 2014 and a 93% decline between 1985 and 2014 (70% and 92%, respectively for 2015). Based on SCA, the estimated SSB at the start of 2014 was 28,700 t (95% CI: 25,280-38,960), a 74% decline from the 2000 level and a 92% decline from the 1985 level. Based on these models there is no chance that SSB in 2014 and 2015 was above the LRP of 80,000 t. SSB at the start of 2014 is estimated to be 32% of LRP (95% CI: 26-39%) based on VPA or 36% of LRP (95% CI: 32-49%) based on SCA. The VPA estimate of SSB at the start of 2015 is 39% of the LRP (95% CI: 28-53%).

VPA and SCA estimates of *F* and *M* were similar except for the estimates of *M* of cod 2 – 4 years old (Fig. 38; Table 15). VPA estimates of age 2-4 *M* were considerably greater than the SCA estimates. However, sensitivity analyses indicate that the sGSL cod data are not informative for VPA models with respect to the level of *M* at these young ages (Swain and Benoît 2015 and online supplement). Uncertainty in the VPA estimates of 2-4 *M* was high and the SCA estimates were within the 95% confidence bands around the VPA estimates. There was considerably less uncertainty in the SCA estimates. Based on the SCA results, there was a slight decline in the *M* of 2-4 year old cod between 1970 and 2014. Both VPA and SCA indicated that average *F* was negligible for the 2-4 year age group over the entire time series (though note that these averages are dominated by the more abundant age 2 cod).

Despite the differences between the VPA and SCA estimates of *M* of 2-4 year old cod, estimates of the trends in *F* and *M* were similar between VPA and SCA for older cod. For ages 5-8, *F* progressively increased between 1950 and the mid-1970s and then declined sharply to a lower level in the late 1970s to the mid-1980s. *F* then increased rapidly to a peak in 1991 or 1992, dropping to a very low level in 1993 with the closure of the directed cod fishery. *F* has remained low since then for ages 5-8. During fishery openings in 1999-2002 and 2004-2008 *F* averaged about 3% and 2% annually, respectively, for age 5-8 cod. The average value during the fishery closure since 2009 is an order of magnitude lower, about 0.2% annually. *F* showed a similar pattern for cod aged 9 years and older, except that the VPA estimates were not low in the early 1950s. Just prior to the closure of the directed fishery in 1993, 9+ *F* peaked at 0.775 (54% annually) based on VPA or 0.53 (41% annually) based on SCA. During the fishery openings in 1999-2002 and 2004-2008, annual 9+ *F* averaged about 9-12% and 6-8%, respectively. The estimated fishing mortality of 9+ cod since the fishery closure in 2009 averaged 0.7% or 1% annually, based on SCA or VPA, respectively (F = 0 .0069 or 0.011, respectively).

Estimated *M* of cod 5-8 years old progressively increased beginning in the mid to late 1970s. Estimated *M* increased from about 0.2 in 1971 to 0.67 (VPA) or 0.74 (SCA) in 2014 (i.e., from about 18% annually to 50% annually). Based on VPA, *M* of cod 9 years and older increased from 0.23 (21%) in 1971 to 0.83 (56%) in 2014. For SCA, the estimated increase was from 0.35 (29%) in 1971 to an average of 0.87 (58%) in 2008-2010, declining slightly to 0.75 (53%) in 2014. The estimate for the earlier portion of the time series is higher than that obtained by VPA and by earlier independent studies (see section Mortality Estimates above). The estimate appears to be influenced by the fitting to the proportions at age in the fishery catch in the 1950s and 1960s, which are quite uncertain. If fitting starts in 1971 (Appendix C), the estimate is 0.26, consistent with the estimates from VPA and the earlier studies. Nonetheless, estimates of mortality and biomass for the recent period converge on similar values in all cases (Appendix C).

Estimated abundance trends are similar between VPA and SCA, but the VPA estimates of 2+ abundance are higher than the SCA estimates (Fig. 39; Table 16). This difference results from the much higher VPA estimates of the abundance of age-2 recruits, and is associated with the higher VPA estimates of M for ages 2-4. This large difference in recruit abundance has a relatively small impact on the estimated abundance of adult or commercially available fish. For example, the estimates of 5+ abundance at the start of 1971, 1986, and 2014 were 116, 385, and 29.5 million, respectively, for VPA compared to 134, 383, and 39.3 million, respectively, for SCA. Both VPA and SCA estimates of recruit abundance have been very low since 2005, with the exception of the 2011 year-class. The strength of the 2011 year-class is estimated to be similar to that of the 2001 year-class, but remains weak compared to the year-classes produced in the late 1970s and the 1980s.

Recruitment rate, the number of recruits produced per unit of SSB, is a measure of spawning success and survival at early life history stages. Recruitment rates were unusually strong for year-classes produced in the mid to late 1970s and in recent years (the 2010 to 2012 year-classes). The high recruitment rates in the 1970s have been attributed to reduced predation on early life stages of cod by collapsed pelagic fish stocks (Swain and Sinclair 2000). The cause of the very high recruitment rates in recent years is not understood. While recruitment has been low since the mid-1990s, recruitment rates have been near or above those estimated for earlier periods (the 1950s to early 1970s), indicating that spawning success and survival at early life history stages have not been unusually low since the collapse of this stock and have been unusually high recently.

Stock production in year t was estimated as the 2+ biomass at the start of year t+1 plus the fishery landing in year t minus the 2+ biomass at the start of year t. Surplus production was substantial in most years between 1950 and the mid-1980s (Fig. 40). Since then surplus production has been very low in most years. There has been a production deficit in most years since 1990 based on the VPA model and since 1998 based on the SCA model. While there was some surplus production in 2013, this production is based on young fish not yet exposed to the elevated natural mortality at ages 5 and older.

Because of its more reasonable assumptions (e.g., error in the proportions at age in the catch), the SCA model was used as the basis for advice. Nonetheless, the VPA model leads to essentially the same advice on the status of this stock.

Projections

Using the SCA model, the population was projected forward five years based on the MCMC samples, which propagated uncertainty in model estimates into the projections. These projections assumed that the current productivity conditions would persist over the projection period. For each age group, *M* was set equal to the average of the last 5 years (2010-2014). For each projection year, the weight-at-age vector was randomly selected from those observed over the last 20 years (1994-2013). Fishery catches were set at a constant level for each projection, either at 0 or at the by-catch quota of 300 t. Fishery selectivity-at-age was assumed to remain the same as estimated for 1994-2014. In the SCA model, recruitment rate is assumed to follow an auto-correlated random walk. This approach was extended into the projection period using the average recruitment rate and the auto-correlation coefficient estimated by the model. For each year and iteration of the projection, the log residual in recruitment rate was based on the log residual in the previous year and a log residual that was randomly selected from those observed in the past 63 years. Projections were based on 200,000 MCMC iterations, with every 40th iteration saved to generate posterior results.

With no fishery catch, projected SSB initially increases due to the strong incoming recruitment, and then declines as these fish suffer high natural mortality as they get older (Fig. 41). Based on the projection, there is no chance that SSB equaled or will equal the LRP at the start of 2015 to 2017. The probability of SSB equaling or exceeding the LRP increases to 0.1% at the start of 2019. The probability that SSB will decline between 2015 and 2019 is 79%. A by-catch scenario of 300 t has a negligible effect on the projected trajectory of the stock (Fig. 42).

THE LIMIT REFERENCE POINT

The limit reference point for this stock was established in 2003 based on the model-based stock-recruit relationship as well as the minimum biomass from which the stock had previously recovered (Chouinard et al. 2003). In the 2003 analyses, it was assumed that the maturity schedule had been constant since 1950. Since then, it has been determined that there have been large changes in age at maturation since 1950 (Swain 2011), and these changes have been incorporated into the calculation of SSB in the models used here. There also have been major revisions in the estimation of time trends in natural mortality. These changes have important impacts on the estimates of SSB obtained from population models (Fig. 43). Because of these model changes, it is recommended that the LRP for this stock be re-evaluated before the next assessment. Based on the current models, the LRP would be greater than 80,000 t. For example, *B*recover, the smallest SSB from which the stock has shown a sustained recovery, would be 105,000 t based on the VPA presented here and 130,000 t based on the SCA presented here. A stock-recruit based LRP would likewise be higher than 80,000 t (D.P. Swain, unpublished analyses). This is not an issue for this assessment because SSB is estimated to be well below the current LRP of 80,000 t and, based on the projections, there is little chance (i.e., 0.1% probability) that SSB will reach the current estimate of the LRP over the next five years, and even less chance that it would reach a revised LRP greater than 80,000 t.

ELEVATED NATURAL MORTALITY OF 5+ COD

The extremely high natural mortality of cod five-years and older is the reason for the lack of recovery (and continued decline) of this stock. If *M* were at a normal level (i.e., 0.1-0.2, the estimated level in the 1950s and 1960s) and other components of productivity were at their current levels, this stock would recover quickly at current levels of fishing mortality (Swain and Chouinard 2008). Swain et al. (2011) examined a suite of hypotheses for the causes of this elevated mortality including unreported catch (i.e., some of the increased mortality is unknown fishing mortality, not natural mortality), emigration (i.e., older fish are leaving the ecosystem, not dying), or increased natural mortality due to disease, contaminants, poor fish condition as a result of harsh environmental conditions, life-history change (early maturation, early senescence), heavy parasite loads, and increased predation mortality. The weight of evidence most strongly supported the hypothesis that predation by grey seals was a major cause of the increases in natural mortality. While unreported catch and early maturation combined with poor fish condition may have contributed to increases in M between the late 1970s and mid-1990s, there was no support for these factors as important causes of the high level of M since then.

Grey seal abundance has increased dramatically in the southern Gulf ecosystem (Swain and Benoît 2015) and this increase coincides with the increases in natural mortality of cod (Chouinard et al. 2005). Cod are known to be an important prey of grey seals, and seal foraging areas are seasonally associated with aggregations of large cod (Harvey et al. 2012). Grey seals feeding heavily in the vicinity of overwintering aggregations of cod contain a high proportion of cod in their diet, 57-80% of the male diet based on stomach contents and 31-64% of the diet determined from intestines (Hammill et al. 2014). It is not yet possible to reliably estimate the average annual diet of grey seals due to wide seasonal, spatial and individual variation in diets. Nonetheless, based on the energy requirements of seals and estimates of spatiotemporal overlap between seals and cod, Benoît et al (2011) concluded that it was plausible that predation by grey seals could account for a high proportion of the natural mortality of cod, even if their contribution to the average seal diet was modest (15%). Finally, dramatic changes in the spatial distribution of cod in relation to increased risk of predation by grey seals are consistent with strong predation by grey seals on cod in the southern Gulf (Swain et al. 2015). Swain and Benoît (2015) suggested that cod in the southern Gulf are experiencing a "predator pit" or predation-driven Allee effect as a result of predation by grey seals. Under these conditions, recovery of cod in the southern Gulf is unlikely even in the absence of fishing.

STOCK STATUS INDICATORS

The sGSL cod stock is currently assessed and managed on a four-year cycle. Indicators are needed to characterize stock status in the years between assessments. Suggested indicators are the biomass indices for commercial sizes of cod in the RV and mobile sentinel surveys and the longline sentinel program. Because observation error in the indices can be substantial, changes in stock status should not be inferred from annual observations. Instead, inferences should be based on moving averages. A minimum of a three-year moving average is recommended. Interpretation of changes in sentinel indices can be difficult due to changes in vessels between years in the case of the mobile index and changes in cod distribution in the case of the fixed index. Thus, consideration is given to use of the RV index as the primary indicator. Normally, a large change in the moving average from its value in the last assessment year would trigger an early re-assessment. Given the current status of the stock, an increase in the moving average to a level above the LRP should trigger a re-assessment. Under current conditions it is debatable whether a large decrease in the smoothed indicator should trigger a re-assessment. Currently the directed cod fishery is closed and a by-catch TAC of 300 t is in place. There appear to be no additional fishery management actions that can be taken to improve stock status.

In order to implement this approach it is necessary to re-scale the LRP from the scale of the population to the scale of the RV index. One way to do this is to model the RV biomass index as a function of the estimated SSB:

$$I_t = \beta S_t + \varepsilon_t \qquad (8)$$

where I_t is the RV biomass index in year t for cod 42 cm and longer, S_t is SSB in year t and ε_t is a randomly distributed normal deviate. The model intercept was assumed to be 0 (since I should be 0 when S is 0). This assumption was supported by models that included an intercept (which was not significantly different from 0). The model fit the observed index well and accounted for 94% of the variation in I (Fig. 44). Based on this model, the 80,000 t LRP was estimated to be 47,200 t on the scale of the biomass index (in units of trawlable biomass).

CONCLUSIONS

The outlook for this stock remains grim. Spawning stock biomass is at the lowest level observed in the 65-year record and is declining. Estimated SSB has declined by about 70% from the already low level in 2000 and over 90% from the level in 1985. SSB is estimated to be about 40% of the limit reference point with essentially no chance of recovering to this level over the next five years, even with no fishing mortality. Although the 2011 year-class is estimated to be strong compared to other recent year-classes, it remains weak compared to those produced in the 1980s. SSB is projected to increase slightly in 2016 as the 2011 year-class continues to recruit to the mature stock. However, it is expected to decline from 2016 to 2019 as these fish suffer high natural mortality. With no fishing mortality, the probability that SSB in 2019 will be below the 2015 level is estimated to be 79%.

The ongoing decline of this population is due to the high natural mortality of adult cod (i.e., ages 5 years and older). Natural mortality of about 18% annually is considered normal for adult cod. In this population, natural mortality has increased over the past 35 years for adults and is now estimated to be 50-60% annually. At this level of natural mortality the population is expected to continue to decline even with no fishing mortality. Predation by grey seals is considered to be a major cause of this mortality. Consequently, no recovery of this population is expected at the current level of grey seal abundance in this ecosystem (Swain and Benoît 2015).

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TABLES

Table 1: Landings (t) of southern Gulf of St. Lawrence cod, 1965-2014, by area and time period. The column "stock" indicates the landings used in the analytical assessment, and is the total for 4T, 4Vn (Jan.-Apr.), 4Vn (Nov.-Dec.), and catches of 4T origin in 4Vs. The TAC applies to the traditional management unit, 4TVn (Jan.-Apr.) until 1994.

Year	4T	4Vn(J-A)	4Vn(N-D)	4Vs	Stock	4TVn(J-A)	TAC
1965	46471	16556	2077	-	65104	63027	-
1966	38282	16603	2196	-	57081	54885	-
1967	34245	7071	2096	-	43412	41316	-
1968	37910	8641	2440	-	48991	46551	-
1969	40905	6914	2442	-	50261	47819	-
1970	43410	21055	1523	-	65988	64465	-
1971	40669	15706	1556	-	57931	56375	-
1972	42096	25704	1517	-	69317	67800	-
1973	25756	24879	1308	-	51943	50635	-
1974	28580	20167	1832	-	50579	48747	63000
1975	28853	13618	795	-	43266	42471	50000
1976	17600	15815	3928	-	37343	33415	30000
1977	19536	2683	4665		26884	22219	15000
1978	25453	12439	1128	-	39020	37892	38000
1979	46695	9301	1700	-	57696	55996	46000
1980	36157	18477	2592	-	57226	54634	54000
1981	48132	17045	1970	-	67147	65177	53000
1982	43418	14775	3476	-	61669	58193	60000
1983	48222	13073	2695	-	63990	61295	62000
1984	40652	14712	2200	-	57564	55364	67000
1985	47819	14319	1835	-	63973	62138	67000
1986	48066	15709	1444	3463	68682	63775	60000
1987	43571	7555	1437	2029	54592	51126	45200
1988	44616	7442	1165	2496	55719	52058	54000
1989	43617	9191	1887	2574	57269	52808	54000

Year	4T	4Vn(J-A)	4Vn(N-D)	4Vs	Stock	4TVn(J-A)	TAC
1990	41552	9688	2031	4606	57877	51240	53000
1991	31938	6781	1830	8911	49460	38719	48000
1992	27899	6782	2282	4164	41127	34681	43000
1993	4121	1161	55	-	5337	5282	13000
1994	1198	139	1	-	1338	1337	Moratorium
1995	1032	-	4	-	1036	-	Moratorium
1996	1140	-	2	-	1142	-	Moratorium
1997	1725	< 1	1	-	1726	-	Moratorium
1998	2671	7	15	-	2693	-	3000
1999	6154	6	3	-	6163	-	6000
2000	6038	4	9	-	6051	-	6000
2001	6305	2	16	-	6323	-	6000
2002	5060	8	59	-	5127	-	6000
2003	288	-	1	-	289	-	Moratorium
2004	2259	7	46	-	2312	-	3000
2005	2825	20	6	-	2851	-	4000
2006	3019	3	2	-	3024	-	4000
2007	1343	144	3	-	1490	-	2000
2008	1526	121	1	-	1648	-	2000
2009	149	< 1	-	-	149	-	Moratorium
2010	103	< 1	-	-	103	-	Moratorium
2011	108	5	< 1	-	114	-	Moratorium
2012	150	22	< 1	-	172	-	Moratorium
2013	109	2	< 1	-	111	-	Moratorium
2014	111	3	< 1	-	114	-	Moratorium

Table 2: Landings (t) by gear type of the southern Gulf of St. Lawrence cod stock, 1965-2014.

Year	Otter trawls	Seines	Gillnets	Longlines	Handlines	Misc.	Total
1965	48854	2735	3571	4713	< 0	5231	65104
1966	37023	2444	9414	3062	< 0	5138	57081
1967	24823	2293	9948	2536	2469	1343	43412
1968	29553	1064	12933	1344	2942	1155	48991
1969	28131	1234	9581	5014	5066	1235	50261
1970	43652	1798	9786	6258	3205	1289	65988
1971	36338	2267	9676	3600	4011	2039	57931
1972	50615	2121	7896	1792	2103	4790	69317
1973	36467	2137	8223	925	2135	2056	51943
1974	37923	1765	6141	1352	1292	2106	50579
1975	29080	1983	6330	245	3530	2098	43266
1976	28928	1384	4459	163	1191	1218	37343
1977	14695	3269	5931	692	1299	998	26884
1978	22669	4504	8929	1015	1449	454	39020
1979	31727	8845	12022	1622	1957	1523	57696
1980	32698	10095	4260	2827	1562	5784	57226
1981	34509	12563	4053	7017	1061	7944	67147
1982	32242	11360	4205	5481	916	7465	61669
1983	32880	13857	3010	4754	1286	8203	63990
1984	32316	10732	6891	5058	1903	664	57564
1985	40177	11935	5287	4261	2078	235	63973
1986	41653	15380	4328	5314	1975	32	68682
1987	31961	9759	4792	5926	2106	48	54592
1988	34055	12017	3936	4074	1602	35	55719
1989	34260	15492	2796	3396	1190	135	57269
1990	37354	14094	1962	3289	1048	130	57877

Year	Otter trawls	Seines	Gillnets	Longlines	Handlines	Misc.	Total
1991	35216	9282	1679	2502	778	3	49460
1992	28408	8660	1263	1890	875	31	41127
1993	2143	328	1313	842	705	6	5337
1994	213	412	302	103	153	155	1338
1995	110	379	101	78	101	267	1036
1996	269	398	134	127	214	-	1142
1997	337	599	280	247	195	68	1726
1998	709	828	506	408	238	4	2693
1999	1642	1195	1665	882	777	1	6163
2000	1264	1275	1747	953	812	0	6051
2001	1717	1560	1409	882	743	12	6323
2002	1125	1652	1226	482	337	305	5127
2003	24	79	3	183	< 0	< 0	289
2004	650	569	454	444	194	1	2312
2005	1072	531	542	531	174	1	2851
2006	1224	876	279	471	172	2	3024
2007	562	482	100	281	62	3	1490
2008	709	409	139	282	109	< 0	1648
2009	39	26	5	72	7	< 0	149
2010	11	14	4	65	9	-	103
2011	4	14	5	74	13	< 0	109
2012	7	13	7	104	20	-	150
2013	3	7	8	89	2	< 0	109
2014	9	19	3	80	-	-	111

Table 3: By-catch landings (t) of Atlantic cod from NAFO Division 4T by main species caught. All data are provisional. For the shrimp fishery, cod bycatch estimates are based on observer data since cod are not landed. Rate is the landings of cod divided by the landings of the target species. Landings in this table do not sum to the total landings because trips identified as cod-directed are not included here.

	Atlantic Halibut		American Plaice		Redfish		Shrimp		Turbot		Winter Flounder		Witch flounder		Yellowtail flounder	
Year	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate
1985	0.0	0.000	154.5	0.018	7.2	0.002	-	-	0.0	0.000	24.8	0.023	166.6	0.163	12.1	0.057
1986	0.0	0.000	320.8	0.043	42.1	0.011	-	-	3.7	0.001	6.7	0.003	109.5	0.087	0.0	0.000
1987	0.0	0.000	611.7	0.076	49.8	0.008	-	-	26.9	0.004	6.0	0.003	178.6	0.104	1.6	0.004
1988	0.0	0.000	481.2	0.072	52.7	0.007	-	-	8.4	0.002	3.2	0.002	242.5	0.161	1.4	0.007
1989	0.0	0.000	626.0	0.125	83.3	0.008	-	-	3.0	0.001	14.8	0.007	126.4	0.111	0.0	0.000
1990	0.5	0.002	345.2	0.082	51.7	0.013	-	-	3.5	0.003	0.0	0.000	54.2	0.088	0.0	0.000
1991	1.4	0.013	488.1	0.093	39.3	0.006	0.2	0.0004	1.6	0.002	31.8	0.013	62.2	0.115	0.7	0.013
1992	0.9	0.018	484.7	0.094	50.2	0.006	0.3	0.0006	0.4	0.000	73.2	0.039	82.1	0.136	0.0	0.000
1993	0.0	0.000	147.2	0.095	13.2	0.003	1.1	0.0019	1.1	0.001	17.0	0.010	46.1	0.102	0.0	0.000
1994	13.5	0.165	148.6	0.063	19.9	0.004	0.2	0.0001	0.1	0.000	26.9	0.022	17.3	0.049	0.0	0.000
1995	9.5	0.144	126.5	0.053	0.0	0.000	0.4	0.0002	0.1	0.000	22.3	0.033	16.4	0.060	5.2	0.025
1996	0.3	0.008	87.8	0.063	0.0	0.000	0.4	0.0001	0.0	0.000	36.8	0.044	19.2	0.047	10.3	0.049
1997	27.4	0.325	216.6	0.121	0.0	0.000	0.7	0.0004	0.0	0.000	52.5	0.047	50.6	0.108	122.1	0.150
1998	81.9	0.769	104.1	0.089	0.2	0.001	0.0	0.0000	4.7	0.002	32.1	0.052	66.8	0.127	12.1	0.066
1999	151.4	1.436	363.3	0.236	4.0	0.009	0.1	0.0001	162.3	0.075	30.9	0.048	83.8	0.215	21.7	0.071

	Atlantic Halibut		American Plaice		Redfish		Shrimp		Turbot		Winter Flounder		Witch flounder		Yellowtail flounder	
Year	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate	Catch	Rate
2000	114.8	1.397	307.7	0.217	0.3	0.001	0.1	0.0000	2.1	0.002	38.4	0.067	97.3	0.174	40.1	0.136
2001	120.2	1.224	273.6	0.230	1.3	0.004	0.2	0.0001	36.7	0.056	30.7	0.054	154.9	0.418	15.6	0.049
2002	54.0	0.533	231.6	0.342	18.4	0.040	0.3	0.0001	0.1	0.000	2.2	0.005	61.7	0.106	13.6	0.063
2003	25.6	0.311	25.0	0.064	7.4	0.026	1.0	0.0003	1.4	0.001	0.6	0.001	36.5	0.095	9.6	0.061
2004	29.0	0.215	95.4	0.238	7.5	0.018	2.3	0.0005	1.9	0.001	0.1	0.000	39.2	0.120	4.8	0.025
2005	38.0	0.215	6.3	0.019	10.4	0.032	0.6	0.0002	0.5	0.000	0.0	0.000	35.8	0.078	6.1	0.035
2006	18.4	0.127	11.1	0.023	21.8	0.043	1.1	0.0003	0.4	0.000	0.1	0.000	58.5	0.110	6.0	0.033
2007	7.8	0.062	7.6	0.020	0.4	0.005	0.6	0.0002	0.6	0.001	0.0	0.000	84.4	0.174	4.6	0.032
2008	26.3	0.159	1.6	0.009	5.5	0.016	20.9	0.0073	0.5	0.000	0.0	0.000	70.4	0.162	0.2	0.002
2009	31.3	0.155	11.4	0.090	8.6	0.016	4.2	0.0014	1.2	0.001	0.0	0.000	38.8	0.173	0.1	0.001
2010	40.2	0.161	0.4	0.003	8.2	0.025	1.1	0.0004	2.0	0.002	0.0	0.000	7.2	0.065	4.5	0.024
2011	44.9	0.182	0.9	0.009	3.6	0.008	5.1	0.0013	0.8	0.002	0.1	0.000	5.0	0.047	4.0	0.022
2012	72.5	0.250	0.2	0.003	5.3	0.014	1.7	0.0004	3.3	0.005	0.4	0.001	8.6	0.085	0.1	0.001
2013	68.8	0.190	0.5	0.013	1.4	0.005	20.2	0.0045	6.0	0.012	0.1	0.000	5.5	0.038	0.0	0.000
2014	62.6	0.184	0.1	0.003	2.9	0.010	0.4	0.0002	3.1	0.002	0.1	0.001	17.6	0.117	0.0	0.000

Table 4: Landings at age (numbers, 1000s) of southern Gulf of St. Lawrence cod, 1971-2014. The table includes landings in 4T, 4Vn (Nov.-Apr.), and 4Vs (Jan.-Apr.).

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1971	6	2099	7272	9262	5916	2331	1251	520	130	354	75	120	154	68	29558
1972	3179	22247	12018	6666	7561	3551	952	547	372	120	51	14	47	38	57361
1973	1374	6999	14498	5325	3720	2800	1861	557	338	100	69	47	12	24	37723
1974	2993	5400	5033	9690	3102	1854	1772	1054	260	198	81	29	6	19	31490
1975	1567	8910	6933	2540	3297	1319	1119	801	680	151	53	76	7	67	27519
1976	508	4093	9996	6975	1708	1257	478	285	148	145	47	17	12	10	25679
1977	659	4960	5899	3320	1773	400	284	182	114	50	53	10	4	5	17712
1978	548	10037	10897	4596	2681	1108	244	248	110	72	44	5	13	6	30610
1979	148	5138	15913	11251	3509	1724	865	295	253	66	33	17	16	8	39235
1980	295	1920	14674	14142	9789	1522	808	404	143	30	18	8	14	26	43793
1981	98	3829	7380	19144	13116	6200	913	463	203	71	89	2	14	4	51526
1982	518	1621	10671	8700	12539	7663	2533	444	142	76	5	2	2	1	44917
1983	42	1147	6311	12124	11936	7646	5379	2668	139	51	18	10	5	5	47481
1984	30	1319	4210	7410	9085	6949	5173	2937	942	151	52	7	5	9	38278
1985	175	1561	10307	17163	8342	6094	3975	2277	971	353	26	6	8	6	51265
1986	136	3546	8295	23645	9739	4069	3041	2372	1197	803	159	19	3	2	57027
1987	80	1029	7400	10851	18933	7011	2250	1684	700	417	132	112	14	13	50627
1988	111	1725	5241	11259	9072	12151	6813	1818	970	466	202	51	44	8	49931
1989	71	1658	6065	12398	10714	7316	7628	5171	990	465	153	49	37	15	52730
1990	540	2973	7508	10613	10207	6983	4467	4644	2066	385	122	37	30	30	50603
1991	286	5178	10371	9586	8416	4735	3173	1754	955	587	91	25	16	9	45184
1992	487	3437	12511	9912	5290	3453	2059	910	510	375	112	12	5	9	39081
1993	53	262	904	1174	946	499	223	135	74	36	31	7	9	2	4353
1994	26	54	98	211	281	156	71	28	19	8	4	2	0	0	957
1995	69	133	145	130	223	134	60	24	13	5	2	1	0	0	939
1996	39	84	134	142	124	174	89	34	11	7	3	1	0	0	842

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1997	27	53	120	182	174	180	208	109	38	10	3	2	1	0	1106
1998	70	82	211	329	336	252	206	186	73	24	7	1	0	0	1776
1999	42	199	361	535	776	609	448	252	231	88	22	8	1	1	3571
2000	35	107	344	682	530	822	411	387	186	133	35	12	2	0	3685
2001	25	113	365	945	921	530	480	239	189	76	59	16	2	1	3962
2002	25	64	348	553	890	717	260	243	93	53	17	19	1	0	3283
2003	4	5	13	19	23	29	26	8	10	4	3	2	2	0	150
2004	8	18	65	181	297	359	247	155	32	28	6	4	2	1	1404
2005	7	42	160	330	357	360	307	180	103	16	10	2	0	0	1875
2006	3	110	392	552	462	204	243	185	82	46	5	6	1	1	2291
2007	6	13	42	255	325	247	102	71	38	22	12	3	2	0	1139
2008	3	34	122	171	438	301	121	52	29	20	5	2	1	0	1299
2009	4	6	6	16	16	26	11	10	3	3	1	1	0	0	102
2010	1	3	10	9	16	9	11	6	2	1	0	0	0	0	69
2011	1	3	8	11	12	14	10	5	2	1	0	0	0	0	68
2012	1	6	9	23	29	12	11	7	3	2	0	0	0	0	103
2013	1	2	5	6	9	14	10	8	2	2	2	0	0	0	61
2014	2	4	10	10	9	9	8	2	4	1	2	0	1	0	62

Table 5: Average weight at age (kg) of 3 to 16+ of removals for the southern Gulf of St. Lawrence cod stock, 1971-2014.

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1971	0.76	0.82	1.11	1.40	2.15	3.67	3.83	5.25	6.00	4.78	6.85	7.42	7.96	17.72	1.96
1972	0.36	0.56	0.91	1.33	1.52	2.55	4.82	5.97	7.13	8.08	8.85	10.25	5.65	11.23	1.16
1973	0.46	0.67	0.92	1.28	1.69	2.31	3.59	5.51	6.03	7.95	6.16	6.72	8.86	6.12	1.37
1974	0.60	0.78	1.09	1.49	1.96	2.68	2.89	4.11	5.97	7.07	8.30	6.87	9.84	12.65	1.61
1975	0.48	0.74	1.15	1.76	2.36	2.75	3.22	3.70	4.46	6.95	9.20	6.30	8.39	6.19	1.57
1976	0.46	0.78	1.11	1.54	2.19	2.84	3.23	3.79	4.62	5.09	6.19	9.87	10.45	15.05	1.45
1977	0.52	0.81	1.27	1.79	2.42	3.51	4.27	4.31	5.10	5.57	6.45	8.61	12.56	9.88	1.52
1978	0.40	0.68	1.03	1.66	2.27	2.81	4.33	4.63	6.37	6.46	6.23	5.09	11.56	10.17	1.27
1979	0.51	0.71	1.01	1.42	2.22	3.31	4.07	7.14	6.96	6.69	4.70	8.79	15.52	17.34	1.47
1980	0.58	0.69	0.92	1.22	1.50	2.78	3.08	4.00	7.83	6.01	9.98	5.81	9.13	9.35	1.30
1981	0.50	0.68	0.85	1.13	1.39	1.84	3.19	4.17	4.47	5.60	6.11	7.08	3.49	8.35	1.30
1982	0.75	0.76	0.97	1.16	1.45	1.72	2.27	3.27	4.01	4.14	6.46	6.92	4.18	11.10	1.37
1983	0.33	0.61	0.89	1.14	1.31	1.58	1.73	2.01	4.84	7.63	8.55	10.51	12.09	14.76	1.35
1984	0.45	0.65	0.79	1.09	1.38	1.61	2.07	2.27	3.05	4.93	5.66	8.61	11.74	13.23	1.50
1985	0.44	0.57	0.76	0.99	1.42	1.67	1.83	2.14	2.41	2.89	8.33	5.71	11.41	12.97	1.24
1986	0.43	0.60	0.81	1.01	1.29	1.75	1.98	1.89	2.64	2.23	3.07	4.83	15.36	13.55	1.20
1987	0.27	0.49	0.70	0.86	0.99	1.25	1.85	2.16	2.24	3.15	3.57	4.03	12.41	14.21	1.08
1988	0.40	0.60	0.77	0.92	1.04	1.13	1.29	1.90	2.23	2.72	3.52	5.67	5.92	14.32	1.12
1989	0.53	0.63	0.77	0.90	1.07	1.19	1.22	1.40	1.94	2.16	2.55	3.49	3.41	2.76	1.09
1990	0.56	0.72	0.85	1.03	1.17	1.28	1.36	1.41	1.50	1.84	2.59	3.36	2.81	7.98	1.14
1991	0.53	0.65	0.85	1.01	1.22	1.41	1.51	1.60	1.63	1.73	2.20	2.50	3.08	3.80	1.09
1992	0.55	0.65	0.81	1.00	1.22	1.45	1.61	1.85	1.88	1.91	2.27	5.52	6.58	9.88	1.05
1993	0.41	0.56	0.70	1.00	1.40	1.81	1.93	2.21	2.29	2.09	2.04	3.00	5.84	13.18	1.23
1994	0.34	0.56	0.79	1.04	1.46	1.87	2.26	2.18	2.52	2.41	2.03	2.29	2.38	13.52	1.40
1995	0.25	0.49	0.67	0.90	1.17	1.49	2.11	2.52	2.98	3.39	4.87	4.93	4.19	10.16	1.08

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1996	0.36	0.47	0.81	0.99	1.37	1.68	2.07	2.64	3.29	2.88	3.59	4.82	6.03	5.40	1.32
1997	0.24	0.56	0.80	1.15	1.42	1.85	2.03	2.28	2.56	2.89	2.77	3.36	2.21	4.67	1.57
1998	0.30	0.52	0.96	1.19	1.53	1.74	1.96	2.11	2.46	3.01	2.84	3.74	5.44	3.99	1.48
1999	0.32	0.69	0.92	1.28	1.61	1.95	2.10	2.58	2.58	2.94	3.62	3.82	4.63	5.52	1.73
2000	0.30	0.56	0.88	1.18	1.46	1.81	2.10	2.15	2.32	2.53	2.94	3.63	3.83	4.68	1.64
2001	0.29	0.65	0.88	1.22	1.52	1.87	2.12	2.26	2.35	2.44	2.32	2.71	3.36	2.89	1.60
2002	0.28	0.69	0.90	1.13	1.44	1.83	2.0	2.27	2.47	2.56	2.68	2.53	4.93	4.78	1.56
2003	0.28	0.49	0.87	1.21	1.52	1.96	2.55	2.80	2.78	3.77	2.84	3.82	3.86	3.36	1.93
2004	0.33	0.56	0.84	1.08	1.40	1.72	1.91	2.26	2.65	2.49	2.62	2.93	2.80	2.75	1.65
2005	0.42	0.68	0.85	1.06	1.31	1.50	1.86	2.21	2.52	3.30	3.17	3.79	4.39	4.70	1.52
2006	0.35	0.68	0.81	0.99	1.22	1.50	1.73	2.16	2.64	3.00	3.11	3.32	2.97	4.23	1.32
2007	0.32	0.46	0.71	0.93	1.14	1.37	1.61	1.95	2.34	2.22	2.57	2.80	2.37	4.95	1.29
2008	0.25	0.60	0.76	0.95	1.15	1.37	1.77	2.08	2.32	2.27	2.67	2.88	2.13	4.20	1.27
2009	0.25	0.42	0.76	1.05	1.19	1.60	1.96	2.28	2.46	2.59	2.84	2.95	2.55	3.14	1.45
2010	0.29	0.59	0.82	1.20	1.41	1.69	1.92	2.16	2.05	3.43	2.92	3.13	3.67	2.15	1.50
2011	0.20	0.70	1.07	1.25	1.62	1.97	2.23	2.46	2.62	3.02	2.38	1.78	2.49	7.50	1.69
2012	0.27	0.65	1.13	1.53	1.56	1.96	2.09	2.46	2.80	2.27	2.51	2.01	2.67	3.19	1.66
2013	0.23	0.65	0.82	1.11	1.39	1.82	2.09	2.51	2.67	3.18	2.90	3.58	2.96	-	1.82
2014	0.26	0.52	1.10	1.30	1.83	1.99	2.36	2.92	3.10	2.92	3.74	2.75	6.31	-	1.82

Table 6: Mean numbers per tow at age of southern Gulf of St. Lawrence cod from the annual research vessel surveys, 1971-2014. In 1995, set 127 where approximately 6,600 age 1-3 cod were caught is included. This set is considered anomalous and has not been included in the index (see Sinclair et al. 1997). In 2002, two large sets (47 and 48) are included. The 2003 survey is incomplete and estimates for missing strata and strata sampled with only one set were obtained using the August 2003 sentinel survey (see text for details).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	0+	3+	5+
1971	0.00	0.10	0.73	8.72	8.84	7.90	6.09	3.99	1.24	0.32	0.35	0.25	0.11	0.02	0.11	0.13	0.28	39.16	38.34	20.78
1972	0.00	0.53	3.60	7.85	18.02	6.84	5.77	3.97	2.40	0.49	0.40	0.44	0.14	0.06	0.05	0.05	0.08	50.70	46.56	20.70
1973	0.03	0.12	6.20	12.24	5.79	9.25	4.32	3.07	2.25	1.43	0.38	0.11	0.27	0.04	0.07	0.02	0.19	45.77	39.42	21.40
1974	0.00	0.14	3.55	14.51	11.03	4.73	5.67	2.12	1.44	1.46	0.49	0.19	0.10	0.24	0.00	0.04	0.13	45.83	42.13	16.59
1975	0.00	0.54	8.19	6.27	9.24	7.24	2.46	1.73	1.14	0.51	0.35	0.43	0.11	0.05	0.01	0.01	0.00	38.27	29.54	14.03
1976	0.00	4.30	9.85	38.38	9.91	7.45	3.36	0.92	0.64	0.34	0.31	0.27	0.09	0.05	0.02	0.03	0.03	75.95	61.80	13.51
1977	0.01	1.05	30.26	26.55	19.01	7.08	3.69	1.91	0.91	0.64	0.41	0.34	0.33	0.32	0.00	0.06	0.10	92.66	61.33	15.77
1978	0.00	1.23	9.29	54.73	40.86	19.72	5.55	3.21	1.01	0.43	0.54	0.64	0.11	0.00	0.15	0.05	0.00	137.50	126.99	31.40
1979	0.19	0.18	32.52	31.85	65.04	39.17	15.98	4.14	1.71	0.82	0.26	0.26	0.21	0.07	0.06	0.04	0.02	192.51	159.63	62.74
1980	0.32	1.41	6.73	41.14	30.51	53.54	26.39	9.50	1.65	0.80	0.34	0.11	0.04	0.03	0.05	0.02	0.02	172.60	164.14	92.48
1981	0.28	5.34	21.91	21.92	67.15	56.53	55.54	23.42	12.72	1.77	0.74	0.36	0.14	0.06	0.06	0.10	0.14	268.18	240.66	151.59
1982	0.34	4.74	38.42	23.22	27.50	31.90	50.82	26.51	12.83	4.05	0.47	0.20	0.13	0.07	0.02	0.00	0.03	221.25	177.75	127.03
1983	0.01	7.62	24.76	53.29	48.05	26.14	18.58	16.02	10.65	5.03	3.28	0.82	0.16	0.43	0.05	0.07	0.00	214.95	182.56	81.22
1984	0.00	1.91	11.39	16.73	37.11	49.22	17.56	9.89	10.34	4.70	2.09	0.79	0.07	0.04	0.07	0.02	0.02	161.96	148.66	94.82
1985	4.31	9.73	15.60	38.91	41.96	67.95	70.28	15.59	6.49	4.46	2.06	1.52	0.39	0.17	0.00	0.00	0.07	279.48	249.84	168.97
1986	2.06	7.11	24.72	35.35	36.85	37.13	44.32	32.04	9.52	2.01	2.76	1.09	0.77	0.21	0.13	0.00	0.05	236.10	202.22	130.03
1987	0.43	0.84	12.75	25.03	23.10	31.71	23.94	31.04	11.11	2.49	1.76	0.66	0.53	0.23	0.11	0.03	0.02	165.76	151.74	103.61
1988	1.70	3.89	19.05	70.02	64.56	51.26	35.85	19.35	20.93	12.17	2.38	0.54	0.32	0.27	0.10	0.11	0.00	302.51	277.87	143.29

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	0+	3+	5+
1989	0.28	12.78	27.01	34.63	32.49	29.46	30.93	16.98	10.84	10.62	6.99	1.33	0.43	0.23	0.18	0.05	0.12	215.35	175.27	108.16
1990	0.20	2.07	6.62	35.40	26.35	19.31	13.64	9.41	5.31	3.13	3.61	1.69	0.34	0.06	0.09	0.02	0.01	127.26	118.38	56.63
1991	1.47	2.74	7.70	15.89	33.24	26.37	10.18	5.85	3.97	1.66	1.05	1.08	0.63	0.08	0.02	0.01	0.01	111.95	100.05	50.91
1992	0.61	1.92	4.69	9.81	13.78	12.24	6.58	2.55	1.20	0.75	0.32	0.20	0.10	0.06	0.01	0.00	0.01	54.83	47.61	24.02
1993	0.66	0.60	6.51	9.17	14.01	16.45	10.80	4.94	1.61	0.65	0.37	0.11	0.05	0.12	0.02	0.02	0.01	66.09	58.31	35.14
1994	1.25	0.66	1.79	7.61	9.07	9.73	12.03	7.76	2.79	1.12	0.41	0.30	0.08	0.04	0.02	0.00	0.01	54.67	50.97	34.29
1995a	8.25	1.12	4.17	5.86	10.23	10.11	8.01	10.39	4.82	1.82	0.57	0.30	0.12	0.03	0.03	0.02	0.00	65.84	52.29	36.21
1996	0.78	2.73	2.20	7.20	12.49	11.03	9.70	7.42	8.06	3.81	1.11	0.38	0.11	0.10	0.01	0.01	0.03	67.15	61.44	41.75
1997	2.46	2.41	4.70	5.54	6.17	10.37	7.03	5.04	3.38	3.84	1.42	0.39	0.06	0.02	0.01	0.00	0.01	52.85	43.29	31.57
1998	0.42	3.12	5.23	7.93	7.38	5.85	7.59	4.88	3.29	2.80	2.46	0.77	0.17	0.10	0.06	0.01	0.00	52.07	43.30	27.99
1999	4.63	2.12	6.39	8.70	12.88	12.25	5.47	6.61	3.65	3.37	1.31	1.70	0.53	0.14	0.03	0.02	0.00	69.79	56.65	35.07
2000	0.36	1.05	2.45	6.86	9.33	9.93	8.23	3.34	4.01	1.50	1.13	0.84	0.40	0.23	0.01	0.01	0.00	49.67	45.80	29.62
2001	8.93	71.05	2.00	4.38	7.77	8.75	7.60	4.98	2.43	1.49	0.93	0.48	0.25	0.08	0.05	0.00	0.02	121.17	39.19	27.05
2002b	0.58	6.80	2.83	4.81	15.42	21.10	14.52	9.17	5.61	1.34	1.12	0.55	0.23	0.19	0.06	0.00	0.00	84.33	74.12	53.89
2003c	0.41	3.28	2.36	2.98	2.57	2.56	2.70	3.10	2.47	1.10	0.35	0.25	0.07	0.06	0.04	0.01	0.00	24.29	18.24	12.70
2004	1.90	0.70	11.37	12.92	11.74	9.42	5.52	5.67	4.40	2.42	1.45	0.21	0.31	0.03	0.03	0.00	0.04	68.12	54.16	29.50
2005	1.18	2.01	0.97	6.27	9.88	6.82	3.14	1.21	0.97	0.75	0.41	0.30	0.07	0.04	0.00	0.00	0.04	34.05	29.89	13.75
2006	1.42	0.32	2.74	2.75	6.10	12.25	7.10	2.97	0.79	0.77	0.36	0.17	0.16	0.01	0.00	0.00	0.00	37.90	33.42	24.58
2007	0.61	2.62	1.60	4.11	5.75	4.81	7.36	4.08	1.53	0.54	0.37	0.11	0.09	0.01	0.00	0.01	0.02	33.61	28.79	18.93
2008	1.73	1.22	1.87	3.73	2.51	5.71	3.17	7.16	4.39	1.77	0.45	0.31	0.01	0.01	0.00	0.00	0.00	34.03	29.21	22.98
2009	0.30	0.50	1.69	10.39	15.24	5.18	5.43	1.99	3.29	1.20	0.52	0.04	0.05	0.02	0.00	0.01	0.00	45.85	43.35	17.73

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	0+	3+	5+
2010	1.00	1.44	3.04	3.29	3.17	5.06	1.17	1.66	0.87	1.30	0.60	0.16	0.04	0.07	0.00	0.00	0.01	22.88	17.40	10.94
2011	1.92	0.32	1.09	3.89	2.61	2.00	2.15	0.35	0.58	0.18	0.32	0.08	0.05	0.00	0.00	0.00	0.00	15.54	12.21	5.71
2012	3.15	0.69	1.75	2.67	5.61	1.11	1.08	1.06	0.13	0.22	0.10	0.08	0.05	0.01	0.00	0.00	0.00	17.72	12.13	3.85
2013	0.08	1.33	12.96	20.78	11.81	10.23	3.98	2.43	1.93	0.37	0.27	0.09	0.10	0.03	0.02	0.00	0.00	66.40	52.04	19.46
2014	0.00	0.29	3.84	16.04	9.36	4.17	2.83	0.47	0.60	0.39	0.13	0.07	0.03	0.03	0.01	0.00	0.00	38.23	34.11	8.71

Table 7: Mean weight (kg) at age of southern Gulf cod from research vessel surveys, 1960-2014. Data from 1960 to 1970 are from non-stratified-random surveys.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1960	-	-	0.35	0.67	1.12	1.72	2.00	2.77	3.57	3.25	3.71	3.31	4.29	12.85	5.98
1961	-	-	0.31	0.55	0.90	1.36	2.08	2.75	3.41	4.83	6.51	6.87	7.56	9.01	14.86
1962	-	-	0.36	0.65	0.93	1.33	1.96	2.86	5.64	7.22	7.90	11.03	-	14.86	-
1963	-	-	0.38	0.61	0.92	1.09	1.46	2.00	2.79	4.91	2.99	8.15	9.04	5.98	-
1964	-	-	0.40	0.58	0.91	1.20	1.35	1.95	2.55	4.28	6.71	8.99	-	4.53	-
1965	-	-	0.40	0.69	1.18	1.24	1.66	2.01	2.52	2.88	4.93	-	8.31	-	9.38
1966	-	-	0.39	0.79	1.29	1.58	1.91	2.26	2.43	3.36	4.75	6.53	7.82	9.95	-
1967	-	-	0.45	0.70	1.45	1.88	2.38	2.46	2.86	4.14	4.62	6.17	8.00	10.19	11.18
1968	-	-	0.41	0.79	1.34	1.88	2.64	3.85	2.58	3.08	3.90	5.61	6.41	10.22	10.60
1969	-	-	0.44	0.85	1.40	1.96	2.63	3.51	4.23	2.84	7.19	6.73	6.82	7.04	10.77
1970	-	-	0.42	0.75	1.22	1.73	2.49	3.30	4.44	4.77	3.70	4.25	5.29	4.96	8.62
1971	0.03	0.12	0.41	0.75	1.15	1.42	2.00	3.03	4.59	5.49	6.31	4.43	3.56	4.26	6.61
1972	0.05	0.15	0.39	0.73	1.22	1.55	1.95	2.72	3.92	4.61	6.00	6.30	5.08	10.77	6.13
1973	0.03	0.17	0.34	0.75	1.18	1.56	1.94	2.39	2.84	4.97	5.29	8.78	3.58	2.98	4.89
1974	0.04	0.21	0.46	0.74	1.20	1.67	2.13	2.31	2.42	3.51	4.39	5.66	11.03	-	4.31
1975	0.04	0.09	0.30	0.74	1.20	1.80	2.39	2.87	3.22	4.29	4.81	5.99	10.04	11.35	13.88
1976	0.05	0.15	0.26	0.73	1.32	1.87	2.50	3.04	3.06	4.07	5.31	4.41	6.97	4.90	3.37
1977	0.05	0.13	0.34	0.66	1.35	1.95	2.70	4.33	3.88	5.38	4.92	5.87	8.75	-	14.96
1978	0.03	0.16	0.33	0.74	1.22	2.06	2.49	3.63	5.40	6.57	9.46	9.03	-	7.37	10.47

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1979	0.02	0.11	0.26	0.59	0.97	1.48	2.18	2.81	3.65	6.94	7.37	6.41	11.97	4.84	13.29
1980	0.03	0.12	0.35	0.61	0.94	1.24	1.64	3.05	3.79	4.61	5.16	6.45	9.35	10.22	7.77
1981	0.03	0.08	0.30	0.65	0.87	1.18	1.42	1.78	3.09	3.89	4.58	7.67	11.49	9.52	11.67
1982	0.06	0.17	0.28	0.60	0.94	1.13	1.43	1.67	2.18	4.03	5.77	9.91	7.61	13.10	-
1983	0.04	0.13	0.26	0.43	0.74	1.17	1.29	1.54	1.97	1.97	4.60	5.94	12.38	3.94	9.41
1984	0.07	0.13	0.27	0.42	0.60	1.00	1.37	1.45	1.92	2.21	3.45	11.59	7.44	11.59	7.44
1985	0.03	0.13	0.32	0.50	0.69	0.83	1.14	1.72	1.70	1.92	2.65	5.90	12.66	-	-
1986	0.05	0.14	0.27	0.51	0.65	0.81	1.04	1.32	2.29	1.79	2.73	3.56	6.65	11.55	-
1987	0.06	0.12	0.25	0.42	0.65	0.79	0.93	1.13	1.49	1.79	2.36	2.18	4.45	6.77	15.66
1988	0.05	0.16	0.30	0.47	0.66	0.85	0.94	1.06	1.27	2.40	2.48	3.62	3.97	13.91	15.32
1989	0.05	0.13	0.28	0.49	0.70	0.89	1.06	1.11	1.17	1.29	2.03	3.59	5.16	6.94	7.66
1990	0.05	0.18	0.33	0.54	0.76	0.96	1.14	1.24	1.27	1.35	1.44	2.34	6.47	8.74	5.66
1991	0.05	0.15	0.27	0.48	0.69	0.93	1.08	1.24	1.40	1.36	1.37	1.68	3.88	7.91	18.61
1992	0.04	0.17	0.30	0.43	0.72	0.93	1.10	1.25	1.49	1.89	1.98	1.41	1.43	1.62	-
1993	0.05	0.14	0.30	0.45	0.64	0.91	1.06	1.26	1.41	2.21	1.49	2.47	1.53	5.23	8.81
1994	0.04	0.14	0.31	0.46	0.66	0.83	1.12	1.34	1.49	1.58	2.42	2.83	1.96	1.83	-
1995	0.06	0.14	0.25	0.50	0.67	0.84	1.03	1.25	1.60	2.33	2.54	3.36	3.60	6.62	8.59
1996	0.03	0.19	0.34	0.45	0.77	0.93	1.11	1.29	1.58	2.36	2.59	4.33	3.54	1.76	4.19
1997	0.03	0.13	0.22	0.56	0.77	1.09	1.28	1.55	1.63	1.97	2.25	2.34	3.02	2.97	-
1998	0.04	0.13	0.30	0.45	0.79	1.05	1.36	1.49	1.76	1.83	2.32	2.39	3.09	3.47	3.55
1999	0.04	0.15	0.28	0.49	0.74	0.99	1.25	1.53	1.61	1.77	1.69	1.90	2.57	3.54	2.21

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2000	0.06	0.15	0.32	0.47	0.79	1.03	1.30	1.48	1.78	1.61	1.74	2.05	2.84	3.17	3.17
2001	0.03	0.10	0.32	0.54	0.78	1.05	1.34	1.56	1.89	2.05	2.13	2.31	3.30	3.21	-
2002	0.02	0.11	0.27	0.48	0.67	0.89	1.13	1.43	1.55	1.91	2.12	3.07	2.24	3.09	-
2003	0.03	0.12	0.26	0.41	0.78	1.07	1.25	1.49	1.79	1.97	1.98	2.46	2.22	3.05	4.13
2004	0.06	0.12	0.21	0.37	0.67	0.96	1.23	1.52	1.69	2.09	2.37	2.36	3.90	4.19	-
2005	0.03	0.14	0.30	0.37	0.60	0.88	1.18	1.42	1.63	1.93	2.03	2.97	2.01	-	-
2006	0.04	0.16	0.24	0.53	0.65	0.88	1.12	1.41	1.58	1.94	1.91	2.29	1.90	-	-
2007	0.03	0.08	0.33	0.47	0.71	0.89	1.06	1.27	1.51	1.65	2.27	2.81	1.78	-	3.62
2008	0.02	0.09	0.21	0.43	0.61	0.86	1.04	1.31	1.46	1.71	1.74	3.38	1.91	-	-
2009	0.01	0.16	0.26	0.40	0.56	0.82	0.98	1.24	1.44	1.68	2.55	2.20	1.49	-	2.44
2010	0.02	0.06	0.26	0.41	0.60	0.91	1.13	1.38	1.57	1.63	1.79	1.48	1.47	-	-
2011	0.03	0.10	0.17	0.33	0.62	0.86	1.13	1.30	1.54	2.05	1.64	1.82	-	-	-
2012	0.01	0.08	0.23	0.35	0.69	0.91	1.19	1.37	1.72	1.78	2.01	2.69	6.37	-	-
2013	0.04	0.11	0.19	0.32	0.54	0.72	0.97	1.40	1.93	2.37	1.70	3.06	2.91	1.77	-
2014	0.05	0.13	0.21	0.36	0.60	0.85	1.24	1.52	1.96	2.42	2.84	4.10	3.91	2.26	-

Table 8: Mean length (cm) at age of southern Gulf cod from research vessel surveys, 1971-2014.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1971	14.5	22.9	35.2	43.0	49.5	53.1	59.5	67.8	77.8	82.6	86.0	74.4	73.0	75.7	87.6
1972	17.0	24.8	34.4	42.2	50.0	53.9	57.7	64.1	71.8	75.9	82.0	82.3	77.7	101.0	85.0
1973	14.3	26.4	33.3	43.1	49.8	54.4	58.3	62.0	65.2	77.9	79.5	94.0	70.7	66.4	79.0
1974	16.9	28.2	36.2	42.5	49.6	55.4	59.7	61.2	62.0	70.0	73.4	81.0	102.2	-	76.0
1975	15.8	19.7	30.5	41.6	48.9	56.1	61.5	65.4	67.8	73.4	77.4	82.4	100.3	104.7	112.0
1976	17.2	25.2	30.3	42.3	51.4	57.4	62.9	66.7	66.5	73.5	79.6	74.7	85.0	79.0	70.0
1977	17.1	24.0	32.7	41.0	52.1	58.6	65.2	75.9	73.1	81.1	78.9	83.0	92.1	-	114.7
1978	15.9	26.6	33.5	42.9	50.2	59.2	62.2	70.1	80.1	84.6	93.3	92.8	-	87.7	98.8
1979	15.2	24.8	31.9	41.1	47.8	54.1	60.4	65.2	70.8	86.1	87.3	83.4	101.7	74.0	105.1
1980	14.5	22.9	33.5	40.4	46.6	51.0	55.6	67.9	73.0	77.8	81.6	88.0	99.5	102.4	94.0
1981	15.2	19.7	31.7	41.4	45.6	50.5	53.6	57.5	68.8	74.3	77.1	93.6	108.0	100.8	108.8
1982	18.1	26.1	31.0	39.8	46.4	49.2	53.2	55.8	60.7	73.8	84.5	101.6	92.3	112.0	-
1983	16.8	25.5	31.9	37.0	44.3	51.3	52.5	55.9	59.4	59.4	71.9	82.9	105.1	76.0	100.0
1984	20.6	25.1	31.8	36.8	41.1	48.2	53.1	53.9	58.9	60.8	69.2	104.4	91.0	104.4	91.0
1985	15.6	24.5	33.2	38.2	42.3	45.1	49.6	56.1	56.2	58.4	63.2	83.6	107.8	-	-
1986	17.2	24.7	30.4	37.9	40.9	44.0	47.5	51.0	59.8	56.1	63.1	68.7	83.1	102.7	-
1987	19.3	24.9	31.1	36.8	42.2	44.9	47.3	49.9	53.6	56.9	59.8	59.1	70.7	79.8	115.1
1988	17.9	26.0	32.0	37.1	41.6	45.2	46.7	48.5	51.1	59.9	63.1	65.7	69.5	110.8	114.8
1989	18.0	24.2	31.2	37.6	42.2	45.7	48.3	49.0	49.9	51.6	57.6	65.5	76.1	81.8	82.8
1990	16.9	26.9	32.9	38.5	43.2	46.6	49.1	50.5	51.1	51.9	52.9	59.6	83.3	88.5	79.2

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	17.3	25.1	30.6	37.4	42.1	46.4	48.6	50.7	52.5	52.0	52.3	55.2	68.8	91.4	124.2
1992	16.5	26.6	32.0	35.8	42.6	46.5	49.0	50.9	53.7	56.1	58.1	53.1	53.6	56.0	-
1993	16.8	24.9	32.0	36.9	41.3	46.3	48.6	51.4	52.5	59.5	54.1	61.4	55.0	77.6	94.0
1994	15.8	24.5	32.5	36.6	41.4	44.6	49.1	52.0	53.6	54.4	60.9	66.0	59.5	58.1	-
1995	18.6	24.9	29.9	38.0	41.9	44.9	47.9	51.0	54.5	60.7	62.1	68.1	70.6	85.8	95.8
1996	15.4	27.8	33.4	36.5	43.5	46.3	48.7	50.9	54.2	60.1	62.7	72.8	67.9	57.0	75.0
1997	14.5	24.5	29.1	39.4	43.7	48.8	51.1	53.7	54.6	57.6	59.7	60.7	67.4	67.5	-
1998	15.9	24.2	31.8	36.4	44.1	48.0	52.3	53.6	56.0	56.8	61.6	62.1	66.7	67.8	72.0
1999	16.7	25.5	31.4	37.6	43.1	47.5	51.0	54.3	55.1	56.8	56.3	58.5	62.8	69.6	62.0
2000	18.3	25.2	32.7	37.3	44.2	48.2	51.9	54.1	57.2	55.6	56.3	59.6	65.5	70.0	70.0
2001	14.3	20.8	32.6	38.7	43.8	48.0	51.9	54.2	57.5	58.9	60.0	61.8	68.7	67.4	-
2002	13.6	22.9	30.8	37.4	41.5	45.7	49.3	52.8	54.4	57.7	59.8	67.0	60.5	67.5	-
2003	15.2	24.0	30.6	35.7	43.8	48.5	51.0	53.8	56.8	58.3	58.8	62.0	61.0	66.4	75.0
2004	19.2	23.9	28.2	34.2	41.4	46.6	50.4	53.8	55.6	59.2	61.9	62.0	73.4	75.1	-
2005	15.4	24.9	31.9	34.1	40.1	45.3	49.8	52.8	55.0	58.0	58.5	65.6	59.2	-	-
2006	16.6	26.4	29.9	39.0	41.6	45.9	49.6	53.3	55.2	58.9	58.6	61.8	59.0	-	-
2007	15.0	20.6	33.4	37.2	43.0	46.0	48.7	51.5	54.4	56.0	61.8	64.9	58.0	-	73.0
2008	12.6	21.9	28.9	36.8	41.0	45.7	48.3	51.7	53.4	55.6	56.8	70.5	59.0	-	-
2009	9.1	25.6	30.2	35.0	39.3	44.7	47.4	51.2	54.0	56.6	64.8	61.9	55.0	-	65.0
2010	12.6	18.5	30.5	35.6	40.7	46.3	49.8	52.9	55.4	56.1	58.2	54.8	54.3	-	-
2011	14.3	22.6	27.2	33.0	41.3	46.0	50.1	52.3	55.6	60.6	56.9	58.6	-	-	-

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2012	8.8	20.6	29.6	34.2	42.8	46.9	51.0	53.3	57.2	58.4	60.8	66.5	89.0	-	-
2013	16.5	22.8	27.7	32.8	39.0	43.0	47.4	53.2	58.8	62.9	56.8	68.3	67.9	58.0	-
2014	17.4	24.1	28.5	34.0	40.3	45.3	51.2	54.7	59.4	63.2	67.4	73.7	74.4	63.0	-

Table 9a: Analysis of deviance results of the generalized linear model analysis of cod catches (kg/tow) by the vessels used in the August sentinel trawl survey. Only parameter estimates for vessel differences are presented.

Source	Deviance	Numerator DF	Denominator DF	F value	Pr > F	Chi-square	Pr > Chi-square
Statistics for Type I analysis							
Intercept	186471						
Year	176864	11	2367	17.27	< 0.0001	189.95	< 0.0001
Strat	125947	25	2367	40.27	< 0.0001	1006.66	< 0.0001
cfvm	119722	9	2367	13.67	< 0.0001	123.07	< 0.0001
Statistics for Type III analysis							
Year	-	11	2367	10.81	< 0.0001	118.91	< 0.0001
Strat	-	25	2367	39.39	< 0.0001	984.63	< 0.0001
cfvm	-	9	2367	13.67	< 0.0001	123.07	< 0.0001

Table 9b: Parameter estimates from the generalized linear model analysis of cod catches (kg/tow) by the vessels used in the August sentinel trawl survey. Only parameter estimates for vessel differences are presented.

CFVN	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-square	Pr > chi-square
				lower	upper		
5688	1	-0.2582	0.1435	-0.5395	-0.0231	3.24	0.072
11502	1	1.2262	0.3489	0.5424	1.91	12.35	0.0004
11870	1	0.4605	0.108	0.2487	0.6722	18.17	<.0001
11873	1	0.1338	0.1778	-0.2148	0.4823	0.57	0.4519
17354	1	0.5522	0.1253	0.3065	0.7978	19.41	<.0001
17790	1	0.1812	0.0873	0.01	0.3523	4.3	0.038
64796	1	-0.4846	0.1837	-0.8446	-0.1246	6.96	0.0083
100278	1	-0.9468	0.2626	-1.4615	-0.4322	13	0.0003
151573	1	0.9324	0.4182	0.1126	1.7521	4.97	0.0258
151347	0	0.0000	0.0000	0.0000	0.0000	-	-

Table 9c: Pairwise comparisons of fishing efficiency of vessels used in the mobile sentinel survey for Atlantic cod. "ns" means not significant (P > 0.05); X refers to differences with P < 0.05; XX refers to differences with P < 0.001. The values on the diagonal are not applicable. The cells in the lower triangular portion in grey shading of the table are a mirror image of the upper triangular portion.

Vessel	5688	11502	11870	11873	17354	17790	64796	100278	151573	151347
5688	na	**XX**	**XX**	ns	**XX**	X	ns	X	X	ns
11502	XX	na	X	X	ns	X	**XX**	**XX**	ns	X
11870	XX	X	na	ns	ns	X	**XX**	**XX**	ns	**XX**
11873	ns	X	ns	na	X	ns	X	X	ns	ns
17354	XX	ns	ns	X	na	X	**XX**	**XX**	ns	**XX**
17790	X	X	X	ns	X	na	X	**XX**	ns	X
64796	ns	XX	XX	X	XX	X	na	ns	X	X
100278	X	XX	XX	X	XX	XX	ns	na	**XX**	X
151573	X	ns	ns	ns	ns	ns	X	XX	na	X
151347	ns	X	XX	ns	XX	X	X	X	X	na

Table 10a: Mean number per tow by age for Atlantic cod in the August sentinel trawl surveys from the southern Gulf of St. Lawrence, 2003 to 2014. Abundance estimates are adjusted for vessel differences.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
2003	0.00	2.61	10.73	11.50	10.86	8.21	6.32	5.84	4.11	1.96	0.51	0.61	0.15	0.17	0.11	0.03	63.70
2004	0.02	0.28	8.61	12.72	13.16	9.71	3.70	3.35	2.32	1.30	0.80	0.18	0.14	0.03	0.05	0.00	56.38
2005	0.00	0.62	0.62	5.40	10.20	7.81	3.79	1.61	1.13	0.56	0.40	0.28	0.05	0.02	0.01	0.01	32.51
2006	0.00	0.20	2.56	2.33	4.22	7.31	4.58	2.23	0.60	0.33	0.19	0.11	0.08	0.00	0.01	0.01	24.74
2007	0.00	0.27	1.52	10.50	11.28	6.73	6.63	2.65	1.27	0.53	0.38	0.11	0.01	0.01	0.00	0.00	41.88
2008	0.02	0.49	3.78	7.24	5.79	8.88	3.29	4.62	1.70	0.74	0.18	0.14	0.10	0.00	0.00	0.00	36.96
2009	0.00	0.13	4.27	14.79	13.92	3.44	5.28	1.64	3.04	1.18	0.34	0.10	0.04	0.02	0.01	0.00	48.19
2010	0.00	0.30	1.42	4.41	4.11	4.98	1.36	1.67	0.55	0.63	0.41	0.20	0.00	0.01	0.03	0.00	20.07
2011	0.00	0.18	1.24	5.76	3.61	5.06	5.47	0.84	0.93	0.41	0.57	0.09	0.04	0.00	0.00	0.01	24.22
2012	0.01	0.03	0.79	2.40	4.60	1.01	1.29	1.23	0.22	0.31	0.11	0.16	0.04	<0.00	<0.00	0.00	12.20
2013	0.01	0.50	1.68	1.93	2.68	4.21	1.13	0.69	0.28	0.19	0.08	0.03	0.05	0.00	0.00	0.00	13.45
2014	0.00	0.03	0.63	3.22	6.86	4.26	2.35	0.62	0.35	0.29	0.05	0.06	0.01	<0.00	0.00	<0.00	18.73

Table 10b: Average weight (kg) by age for cod in the August sentinel trawl surveys conducted in the southern Gulf of St. Lawrence from 2003 to 2014.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Average
2003	-	0.05	0.11	0.27	0.41	0.73	0.99	1.18	1.44	1.83	1.90	1.97	2.30	2.35	2.84	4.10	0.64
2004	<0.00	0.05	0.10	0.21	0.36	0.59	0.90	1.09	1.44	1.67	1.79	1.75	1.77	2.07	1.86	-	0.51
2005	-	0.04	0.13	0.28	0.36	0.58	0.84	1.15	1.35	1.56	1.92	2.32	2.30	2.49	3.51	2.30	0.58
2006	-	0.08	0.12	0.22	0.48	0.60	0.79	1.05	1.34	1.47	1.95	1.94	2.23	-	3.27	2.34	0.62
2007	-	0.02	0.12	0.30	0.41	0.68	0.88	1.08	1.29	1.62	1.84	2.41	2.41	3.39	-	-	0.59
2008	<0.00	0.04	0.11	0.20	0.42	0.61	0.82	1.00	1.36	1.39	1.74	1.93	1.68	-	-	-	0.57
2009	-	0.03	0.14	0.25	0.34	0.54	0.82	1.02	1.28	1.55	1.63	1.78	1.39	2.03	2.12	-	0.49
2010	-	0.02	0.06	0.25	0.37	0.58	0.87	1.15	1.36	1.66	1.65	1.49	-	2.37	1.11	-	0.58
2011	-	0.02	0.09	0.16	0.39	0.55	0.78	1.18	1.40	1.48	1.75	1.76	1.90	-	-	2.12	0.56
2012	0.01	0.02	0.08	0.20	0.32	0.66	0.92	1.18	1.63	1.59	2.40	2.12	2.56	3.05	3.05	-	0.57
2013	<0.00	0.03	0.09	0.21	0.36	0.51	0.71	0.87	1.50	1.27	1.90	3.48	1.99	-	-	-	0.45
2014	-	0.03	0.15	0.26	0.40	0.63	0.80	1.12	1.39	1.85	2.13	2.41	2.60	4.50	-	4.85	0.55

Table 10c: Average length (cm) by age for cod in the August sentinel trawl surveys conducted in the southern Gulf of St. Lawrence from 2003 to 2014.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Average
2003	-	18.3	23.3	31.2	35.8	42.9	47.3	50.0	53.2	57.0	57.8	58.9	60.8	62.0	64.9	74.7	37.8
2004	7.0	17.8	22.1	28.3	33.8	39.9	46.0	49.0	53.6	55.8	57.2	56.7	57.4	60.9	58.7	-	35.3
2005	-	16.7	24.1	31.3	33.8	39.5	44.6	49.3	51.9	54.4	57.9	60.9	61.5	63.6	71.0	62.0	37.9
2006	-	20.9	24.4	29.1	37.9	40.5	44.2	48.4	52.3	54.0	58.6	58.7	61.2	-	70.0	63.0	39.3
2007	-	13.2	23.7	32.4	35.8	42.2	45.7	48.9	51.8	55.4	57.4	63.5	64.0	71.5	-	-	38.8
2008	8.1	16.7	23.5	28.5	36.5	40.8	45.0	47.8	52.4	52.9	56.8	58.1	55.8	-	-	-	37.8
2009	-	14.9	24.4	29.9	33.2	38.4	44.6	48.0	51.7	55.0	56.1	57.8	52.8	60.9	62.0	-	35.4
2010	-	13.3	18.5	30.3	34.4	40.1	45.7	50.0	52.9	55.9	56.4	54.8	-	64.0	50.0	-	37.4
2011	-	14.3	21.7	26.7	35.1	39.7	44.6	50.7	53.6	54.7	57.7	58.1	59.8	-	-	62.0	37.6
2012	10.0	13.4	20.5	28.5	33.1	41.8	46.8	50.9	56.6	56.1	63.1	61.4	65.3	70.0	70.0	-	37.1
2013	6.0	15.1	21.2	28.9	34.0	38.4	42.5	45.6	54.0	51.4	59.0	70.3	59.8	-	-	-	34.6
2014	-	14.2	25.4	30.7	35.5	41.0	44.4	49.4	53.3	57.0	61.1	62.6	65.8	78.9	-	80.9	38.0

Table 11a: Factors in the general linear model for the standardization of longline sentinel catch rates from 1995 to 2014. There are a total number of 1,673 observations in the analysis.

Factor	Number of levels	Values
Year	14	1995 to 2014
Month	4	July, August, September, October
Site	44	17, 19, 22, 23, 24, 25, 28, 29, 30, 31, 34, 35, 40, 45, 50, 51, 52, 53, 60, 61, 65, 68, 71, 72, 75, 76, 85, 89, 97, 98, 103, 104, 109, 110, 113, 114, 115, 116, 121, 122, 123, 124, 125, 126

Table 11b: Analysis of variance results of the general linear model for the standardization of longline sentinel catch rates from 1995 to 2014. There are a total number of 1,673 observations in the analysis.

Source	DF	Sum of squares	Mean square	F value	Pr > F
Overall model					
Model	65	3713.69	57.13	41.01	< 0.0001
Error	1607	2238.59	1.39		
Corrected total	1672	5952.28			
Type I analysis					
Year	19	247.71	13.04	9.36	< 0.0001
Month	3	293.04	97.68	70.12	< 0.0001
Site	42	3172.94	73.79	52.97	< 0.0001
Type III analysis					
Year	19	666.36	35.07	25.18	< 0.0001
Month	3	51.45	17.15	12.31	< 0.0001
Site	43	3172.94	73.79	52.97	< 0.0001

R^2	0.624
Coefficient of variation	30.0
Root Mean Square Error	1.180
CPUE Mean	3.948375

Table 11c: Predicted annual catch rates from the general linear model for the standardization of longline sentinel catch and effort data, 1995 to 2014.

Year	LS Mean (catch rate)	Year	LS Mean (catch rate)
1995	3.759738	2005	3.523238
1996	4.141886	2006	3.265010
1997	4.560084	2007	3.029616
1998	3.805368	2008	2.855352
1999	3.911116	2009	2.558070
2000	4.262020	2010	2.371740
2001	3.852613	2011	2.339187
2002	3.779612	2012	2.642355
2003	3.754902	2013	2.666424
2004	3.983978	2014	2.380830

Table 12a: Standardized longline sentinel survey abundance indices (number per 1000 hooks) by age for southern Gulf of St. Lawrence cod, 1995-2014.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1995	<0.00	0.05	0.22	1.52	3.65	5.35	13.41	9.58	5.40	2.03	1.16	0.42	0.14	0.07	0.00	0.00	42.98
1996	0.00	0.00	0.46	2.03	8.07	11.84	9.87	17.04	12.19	4.84	2.31	1.01	0.73	0.17	0.01	0.05	70.63
1997	0.00	0.00	0.24	2.87	8.65	14.20	19.51	19.29	25.16	13.42	4.30	1.32	0.26	0.25	0.22	0.02	109.72
1998	0.00	<0.00	0.43	1.45	3.85	8.12	8.15	6.81	5.80	7.29	3.59	1.13	0.43	0.11	0.01	0.01	47.18
1999	0.00	<0.00	0.28	2.48	6.45	6.35	12.97	9.14	8.19	5.56	3.05	0.67	0.35	0.19	0.06	0.04	55.78
2000	0.00	<0.00	0.38	1.85	7.55	11.74	11.17	18.63	8.37	6.51	6.76	3.38	1.12	0.52	0.04	0.01	78.04
2001	0.00	0.00	0.27	1.30	4.38	6.59	12.72	8.65	6.08	3.62	2.61	1.83	1.09	0.11	0.02	0.01	49.28
2002	0.00	<0.00	0.56	2.03	6.30	7.90	11.41	10.20	4.33	2.58	1.36	0.86	0.81	0.29	0.15	0.00	48.79
2003	0.00	<0.00	0.10	1.22	5.33	7.92	9.04	9.93	7.34	2.88	2.79	1.06	0.83	0.39	0.31	0.10	49.23
2004	0.00	<0.00	0.32	1.70	6.34	8.70	11.72	10.68	10.98	6.34	1.61	2.46	0.79	0.60	0.10	0.29	62.63
2005	0.00	0.00	0.08	0.43	2.35	5.00	7.00	7.31	6.60	3.89	2.65	0.62	0.62	0.16	0.09	0.08	36.87
2006	0.00	0.00	0.10	0.86	3.42	5.02	5.56	4.82	4.66	2.80	1.96	1.50	0.58	0.27	0.06	0.04	31.63
2007	0.00	0.00	0.05	0.63	1.58	4.98	5.84	4.80	2.08	2.38	1.39	0.97	0.74	0.16	0.13	0.03	25.75
2008	0.00	0.00	0.02	0.23	1.84	3.26	5.34	4.09	2.62	1.62	0.70	0.83	0.28	0.12	0.04	0.04	21.02
2009	0.00	<0.00	0.03	0.47	0.85	4.24	2.05	4.14	1.96	1.63	0.50	0.48	0.24	0.14	0.05	0.00	16.80
2010	0.00	0.00	0.06	0.63	2.23	1.88	3.51	1.89	2.40	1.39	0.47	0.14	0.05	0.02	0.01	0.01	14.70

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
2011	0.00	0.01	0.21	2.15	3.49	3.76	1.66	1.74	1.17	0.85	0.20	0.10	0.03	0.02	0.00	0.00	15.38
2012	0.00	<0.00	0.18	1.23	3.96	5.17	3.74	1.45	1.32	0.69	0.56	0.21	0.06	0.04	0.02	0.01	18.64
2013	0.00	0.00	0.01	0.47	2.01	2.79	3.93	4.05	1.36	1.67	0.63	0.64	0.26	0.09	0.01	0.00	17.91
2014	0.00	0.00	0.02	0.52	2.90	2.73	2.24	1.81	1.42	0.40	0.70	0.25	0.19	0.07	0.02	0.00	13.27

Table 12b: Average weight (kg) at age from the longline sentinel survey catches for southern Gulf of St. Lawrence cod, 1995-2014.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Average
1995	0.09	0.21	0.35	0.62	0.84	1.07	1.43	1.64	2.18	2.67	2.88	2.94	3.86	3.62	-	-	1.56
1996	-	-	0.49	0.67	1.01	1.26	1.62	1.84	2.06	2.53	3.13	2.79	3.29	4.04	2.32	5.36	1.74
1997	-	-	0.38	0.64	0.96	1.35	1.63	2.08	2.14	2.37	2.75	2.95	3.19	3.49	2.16	4.71	1.87
1998	-	0.33	0.53	0.75	1.09	1.42	1.80	1.95	2.14	2.23	2.61	2.97	3.45	3.26	6.15	5.10	1.87
1999	-	0.28	0.54	0.81	1.04	1.43	1.68	2.04	2.06	2.25	2.61	3.25	3.26	2.98	3.08	5.08	1.79
2000	-	0.14	0.53	0.75	1.01	1.33	1.65	1.84	2.20	2.39	2.10	2.56	3.04	2.73	3.99	5.16	1.78
2001	-	-	0.59	0.77	0.97	1.36	1.76	2.00	2.31	2.43	2.68	2.66	2.80	4.02	6.22	4.79	1.88
2002	-	0.23	0.53	0.72	1.06	1.36	1.70	2.07	2.25	2.70	2.75	2.82	2.56	3.24	2.24	-	1.76
2003	-	0.15	0.43	0.61	0.90	1.24	1.57	1.96	2.30	2.51	2.69	3.06	2.53	3.10	2.88	3.07	1.80
2004	-	0.38	0.49	0.67	0.88	1.13	1.51	1.78	1.91	2.36	2.70	2.44	2.89	2.91	3.34	3.00	1.68
2005	-	-	0.60	0.67	0.89	1.23	1.47	1.76	1.96	2.22	2.30	2.73	2.60	2.97	2.94	2.77	1.73
2006	-	-	0.45	0.62	0.86	1.16	1.43	1.74	1.89	2.11	2.49	2.46	2.58	2.79	2.59	2.75	1.63
2007	-	-	0.46	0.61	0.79	1.10	1.36	1.65	1.91	2.05	2.54	2.45	2.68	2.61	3.23	2.88	1.58
2008	-	-	0.31	0.68	0.82	1.14	1.44	1.84	2.04	2.26	2.24	2.50	3.13	2.76	2.39	2.80	1.65
2009	-	0.18	0.37	0.57	0.78	1.08	1.24	1.65	1.74	2.22	2.25	2.28	2.63	2.92	2.47	-	1.51
2010	-	-	0.37	0.67	0.87	1.17	1.41	1.59	1.79	1.94	1.92	2.37	2.11	2.76	3.61	2.15	1.43
2011	-	0.09	0.51	0.76	1.02	1.27	1.63	1.68	1.71	2.12	2.44	1.55	2.28	2.50	-	-	1.32

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Average
2012	-	0.24	0.51	0.71	1.07	1.38	1.60	1.89	2.04	2.44	2.30	2.12	2.61	1.95	2.70	3.19	1.47
2013	-	-	0.71	0.82	0.88	1.18	1.42	1.69	1.94	2.13	2.32	2.59	2.72	2.55	2.63	-	1.57
2014	-	-	0.39	0.82	1.13	1.20	1.64	1.78	2.08	2.32	2.47	2.75	3.25	2.69	4.98	-	1.59

Table 13: Maturity ogives (proportion mature at age) used in the calculation of spawning stock biomass of southern Gulf of St. Lawrence Atlantic cod. Ogives are shown only for years in which the ogive changes.

Year	2	3	4	5	6	7	8	9	10	11	12+
1950	0.006	0.019	0.054	0.148	0.344	0.613	0.828	0.936	0.978	0.993	0.998
1963	0.021	0.049	0.112	0.238	0.440	0.673	0.847	0.937	0.976	0.991	0.996
1964	0.035	0.080	0.171	0.328	0.536	0.732	0.866	0.939	0.973	0.989	0.995
1968	0.006	0.039	0.206	0.624	0.914	0.986	0.998	1.000	1.000	1.000	1.000
1974	0.015	0.104	0.473	0.875	0.982	0.998	1.000	1.000	1.000	1.000	1.000
1977	0.032	0.144	0.465	0.818	0.959	0.992	0.998	1.000	1.000	1.000	1.000
1985	0.020	0.109	0.441	0.842	0.971	0.995	0.999	1.000	1.000	1.000	1.000
1988	0.009	0.073	0.417	0.867	0.983	0.998	1.000	1.000	1.000	1.000	1.000
1994	0.018	0.097	0.382	0.781	0.954	0.992	0.999	1.000	1.000	1.000	1.000
1997	0.013	0.074	0.334	0.765	0.955	0.993	0.999	1.000	1.000	1.000	1.000
1998	0.007	0.052	0.287	0.748	0.956	0.994	0.999	1.000	1.000	1.000	1.000

Table 14a: Beginning of the year population biomass (t) by age for the southern Gulf of St. Lawrence cod stock from the VPA model (1971-2015). Biomass for ages 3+, 5+ and spawning stock biomass (SSB) are also shown. For 2015, the SSB is calculated based on age 2 abundance in 2015 set equal to the average of the estimates for 2012-2014.

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+	SSB
1971	13384	59903	36679	28684	40722	35855	16293	14228	8499	1398	6653	248915	152333	154088
1972	20536	21161	62422	29038	25457	28798	24909	9739	8247	5190	3262	218223	134640	142034
1973	31823	32485	24152	36916	19780	17046	16309	15730	6130	4596	4043	177189	120551	116846
1974	25118	47648	33972	15536	27948	12896	10172	8981	8835	2806	5786	174579	92959	111851
1975	63948	40488	45470	26176	13185	15469	7559	6275	4402	5172	3412	167608	81650	104740
1976	121933	71160	33746	29592	24837	10842	9215	3959	2919	1750	3085	191104	86199	107132
1977	124040	158272	88422	29621	24922	16520	8740	5772	2454	1648	2310	338681	91987	153228
1978	111095	146866	154517	81729	31800	21358	13855	8768	5142	2128	2788	468950	167567	247689
1979	78511	115024	138058	109037	86743	24086	14535	9507	6966	3793	2370	510118	257036	316640
1980	59009	114142	95580	96454	98510	65660	15662	9495	4862	3497	2425	506288	296566	337133
1981	113983	90462	116645	72596	95812	79024	42930	10815	5473	2389	3817	519964	312857	365843
1982	226336	148793	84856	78250	71863	72137	55003	28493	6172	2989	2832	551389	317740	367864
1983	159351	263972	143263	54418	72590	59752	48452	38630	16606	3695	4939	706316	299082	395248
1984	118768	136210	167848	84179	50003	54607	38576	32161	21300	8699	6568	600151	296093	379607
1985	147394	138871	105463	107215	88510	41061	39094	24704	16134	10855	12343	584249	339915	384745
1986	97445	114231	108332	62645	107709	75245	27269	28265	12475	8495	14427	559093	336530	385263
1987	89556	102269	78155	55900	54351	77365	57132	18700	13662	5622	9919	473075	292651	329184
1988	130468	79449	66999	43407	49099	40717	50009	39893	12508	6171	10487	398739	252291	280489
1989	108605	99648	55260	38811	42727	37206	27676	29766	19451	5857	7899	364300	209393	234713
1990	106353	94652	63334	29787	35983	30053	22062	15962	12722	7009	5009	316573	158587	188224
1991	54347	85681	64182	33675	24020	22848	15241	10404	5786	3314	3705	268855	118991	147574
1992	57399	49290	47305	32090	24427	12455	10327	6999	3422	1937	1774	190026	93431	112559
1993	35912	53928	32216	26134	22773	13262	5113	4527	2374	823	1083	162233	76089	89896
1994	30638	37883	33955	18255	25194	19144	10284	3637	2401	1348	872	152974	81136	92988
1995	17765	28476	28771	20142	17649	22618	15715	8771	2403	1592	1518	147655	90407	99034
1996	68638	21865	21176	18307	20559	16279	20033	13185	5666	1522	2109	140701	97660	103985
1997	32386	56177	18187	15428	19379	20237	15754	17863	7890	3203	1670	175789	101425	107418
1998	22387	42342	36088	11680	16758	18261	18130	13988	9919	4414	2366	173946	95516	104417

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+	SSB
1999	26273	32513	35859	28074	10870	14812	14938	14129	6863	4585	3005	165648	97276	101781
2000	20373	32729	26721	24933	29726	9301	11525	11159	6496	2956	3401	158947	99497	101355
2001	26076	23654	26437	18778	25087	27125	7480	8720	5523	3021	2971	148795	98705	101702
2002	21628	24198	18236	16208	17407	19717	20837	4910	3850	2383	2779	130524	88089	89748
2003	26797	29511	21221	11946	15060	14217	14732	15159	2093	1403	2175	127517	76785	80826
2004	13776	33538	22532	13972	10817	13077	11821	11453	7818	1096	1527	127652	71582	75796
2005	27731	18653	24303	14220	12428	8002	8913	7807	5283	3356	1120	104085	61129	65084
2006	11416	22330	15864	17433	12823	9291	5391	5583	3392	2159	1735	96001	57808	58582
2007	18571	14557	16433	10038	15628	9518	6112	3345	2326	1467	1714	81138	50148	52475
2008	10735	16579	10013	10865	7320	11115	6348	3721	1498	985	1440	69883	43292	43968
2009	7222	12919	14917	5306	7874	4585	6854	3762	1760	788	993	59757	31922	35207
2010	5448	11625	11237	10432	4003	5573	3012	4377	1816	839	676	53591	30729	31752
2011	7788	10110	6760	7050	7753	2865	3516	1898	2386	818	649	43805	26935	27319
2012	13238	11599	10219	4555	5307	5469	1764	2161	903	1135	811	43923	22105	24318
2013	16222	15158	8857	7658	3444	3366	3507	1157	1247	402	1046	45842	21827	23166
2014	17467	37928	13938	6088	6142	2358	2225	2291	663	694	811	73140	21273	25540
2015	–	20509	33616	9388	4372	3994	1439	1332	1184	338	696	76868	22743	31012

Table 14b: Beginning of the year population biomass (t) by age for the southern Gulf of St. Lawrence cod stock from the SCA model (1971-2014). Biomass for ages 3+, 5+ and spawning stock biomass (SSB) are indicated. SSB in 2015 is calculated in projections as described in the text.

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+	SSB
1971	6765	28395	36638	42234	46450	43263	20166	13324	11949	5315	7367	255101	190068	186170
1972	10824	14271	39325	38018	37123	33879	31234	14562	7932	6995	7262	230602	177005	174911
1973	14162	22827	22629	38725	29342	23737	21500	18213	8047	3674	6879	195575	150118	144420
1974	11538	28352	32177	22884	32008	19548	14565	12012	9285	3826	6495	181152	120623	135460
1975	27075	25199	37375	34488	18441	21750	12602	8916	6967	5238	4540	175515	112942	128927
1976	41844	41836	29434	37143	29493	13328	14589	7516	5456	4767	5154	188716	117446	131098
1977	50124	77865	74550	39412	35716	20843	9500	8548	4467	2927	5071	278898	126484	165111
1978	38776	88073	112890	104486	43276	28217	16530	7938	6759	4221	6127	418516	217553	262904
1979	22337	61434	126741	126242	101557	31069	18931	10732	5239	4855	6036	492836	304661	345716
1980	16085	50993	80136	140669	106345	67518	21398	13206	6258	2650	6241	495413	364285	378839
1981	29146	39629	83763	97941	132110	77040	43811	15057	8265	3734	5315	506664	383273	404885
1982	50077	62496	61042	93417	86664	95164	51492	29034	8893	5239	5545	498986	375448	392973
1983	31084	97969	100961	65801	81421	62373	63405	35296	15905	5660	9165	537956	339026	385111
1984	24164	45477	106560	100754	53943	55324	39522	40860	19770	9765	9573	481548	329511	365297
1985	32359	49205	61293	117801	91475	39301	39001	26323	22312	11196	16102	474009	363512	375078
1986	20106	44178	67608	64012	106457	70521	26193	29244	13860	12631	15704	450408	338622	360086
1987	21104	37785	54111	63105	51718	71828	46911	17134	13676	7482	15243	378994	287098	303635
1988	26128	34322	45363	54850	51394	35038	45806	28840	10408	6406	15754	328182	248496	261913

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+	SSB
1989	24152	37287	44592	49111	48010	34835	21655	26709	13273	5212	11700	292384	210504	224626
1990	23538	39965	44963	45637	39834	29759	19420	11646	11620	5444	6960	255247	170319	185397
1991	14185	35796	51188	45425	33553	21081	14616	9237	4445	4335	4162	223837	136853	154294
1992	13818	23719	36429	48498	30978	16436	9507	6606	3732	1812	2610	180327	120178	130215
1993	10629	23236	27802	36588	34636	15901	7711	4355	2946	1287	1859	156320	105282	113185
1994	11453	19564	25532	27539	32524	26898	11791	5558	2542	1950	1805	155704	110608	114684
1995	7125	18291	25534	26033	24392	26726	20272	9226	4051	1834	2887	159246	115421	119990
1996	15865	14845	23042	27572	24229	20481	21526	15433	6566	2861	3369	159925	122038	125202
1997	9110	21763	20706	28180	26439	21567	17876	17308	10367	4177	3295	171676	129208	129859
1998	7029	19733	23161	22060	27657	22508	17340	14268	11004	6711	4130	168572	125677	126474
1999	8541	16750	27426	29566	18687	22224	16629	12059	8058	5920	5581	162899	118723	119102
2000	6032	17521	22668	31439	28403	14891	15982	11262	6302	4032	6082	158582	118393	116578
2001	6908	11673	23585	26545	28812	23438	11088	11434	6302	3496	5710	152083	116825	116145
2002	5291	10804	15166	24373	22341	20660	15966	6831	6016	3184	5148	130488	104519	102210
2003	6865	12260	16087	16869	20556	16510	13934	10254	3518	2818	4159	116964	88617	88655
2004	3826	14658	15968	18068	14016	16370	12579	9925	6102	2140	3505	113331	82704	82795
2005	6081	8875	18192	17248	15296	9909	10637	7995	5213	2999	2856	99218	72151	72789
2006	2881	8436	13002	22460	15180	11194	6606	6535	3861	2364	2422	92061	70622	68413
2007	4070	6333	10697	14208	19544	11006	7140	3889	2853	1840	2212	79723	62692	61612

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+	SSB
2008	3126	6300	7552	12252	9805	13164	7013	4191	1727	1206	1841	65050	51198	50111
2009	2276	6579	9911	7001	8516	5900	7825	4048	1896	883	1196	53755	37265	38286
2010	1390	6408	10013	12127	5200	5932	3815	4918	1885	878	766	51942	35521	35412
2011	2282	4495	6496	10950	9199	3801	3821	2454	2622	833	689	45358	34367	33292
2012	3202	5835	7800	7513	8265	6503	2350	2358	1209	1284	864	43980	30346	30612
2013	2933	6189	7521	9866	5433	5019	3991	1478	1461	582	1237	42777	29067	28808
2014	3949	11511	9553	8677	7340	3448	3072	2420	918	880	1120	48940	27876	28709
2015	-	-	-	-	-	-	-	-	-	-	-	-	31993	34034

Table 15a: The instantaneous rate of fishing mortality for the southern Gulf of St. Lawrence cod stock from the VPA model, 1971 to 2014.

Year	2	3	4	5	6	7	8	9	10	11	12+	5-8	9+
1971	0.000	0.000	0.046	0.296	0.395	0.406	0.557	0.479	0.410	0.829	0.829	0.373	0.543
1972	0.000	0.047	0.316	0.563	0.477	0.642	0.449	0.471	0.416	0.611	0.611	0.544	0.488
1973	0.000	0.014	0.249	0.505	0.518	0.529	0.516	0.458	0.593	0.520	0.520	0.512	0.491
1974	0.000	0.025	0.121	0.409	0.752	0.647	0.545	0.752	0.546	0.661	0.661	0.599	0.663
1975	0.000	0.014	0.178	0.320	0.370	0.623	0.634	0.785	1.053	0.922	0.922	0.399	0.897
1976	0.000	0.002	0.086	0.457	0.614	0.455	0.513	0.518	0.509	0.608	0.608	0.508	0.543
1977	0.000	0.001	0.035	0.246	0.268	0.307	0.181	0.215	0.420	0.434	0.434	0.257	0.310
1978	0.000	0.001	0.049	0.141	0.309	0.362	0.322	0.168	0.327	0.546	0.546	0.191	0.286
1979	0.000	0.000	0.025	0.147	0.214	0.415	0.424	0.479	0.355	0.754	0.754	0.189	0.498
1980	0.000	0.001	0.012	0.134	0.192	0.298	0.325	0.388	0.500	0.334	0.334	0.183	0.406
1981	0.000	0.000	0.024	0.086	0.266	0.282	0.321	0.360	0.475	0.603	0.603	0.209	0.428
1982	0.000	0.001	0.012	0.128	0.144	0.291	0.275	0.232	0.355	0.308	0.308	0.186	0.249
1983	0.000	0.000	0.004	0.091	0.220	0.315	0.305	0.357	0.500	0.215	0.215	0.207	0.388
1984	0.000	0.000	0.004	0.029	0.156	0.271	0.326	0.401	0.422	0.413	0.413	0.117	0.409
1985	0.000	0.000	0.008	0.060	0.170	0.282	0.315	0.366	0.396	0.304	0.304	0.134	0.361
1986	0.000	0.000	0.021	0.091	0.206	0.148	0.234	0.303	0.516	0.498	0.498	0.159	0.404
1987	0.000	0.000	0.007	0.092	0.179	0.279	0.166	0.235	0.368	0.379	0.379	0.178	0.301
1988	0.000	0.000	0.014	0.077	0.219	0.250	0.325	0.295	0.420	0.528	0.528	0.199	0.340
1989	0.000	0.000	0.019	0.110	0.298	0.383	0.376	0.446	0.557	0.630	0.630	0.259	0.500
1990	0.000	0.002	0.030	0.198	0.332	0.506	0.548	0.552	0.860	0.711	0.711	0.351	0.690
1991	0.000	0.001	0.052	0.248	0.495	0.576	0.564	0.725	0.717	0.699	0.699	0.403	0.716
1992	0.000	0.003	0.039	0.312	0.478	0.693	0.604	0.736	0.822	0.819	0.819	0.428	0.775
1993	0.000	0.000	0.005	0.022	0.050	0.088	0.146	0.093	0.150	0.227	0.227	0.045	0.130
1994	0.000	0.000	0.001	0.003	0.007	0.018	0.022	0.038	0.024	0.046	0.046	0.009	0.035
1995	0.000	0.001	0.003	0.005	0.006	0.011	0.012	0.014	0.026	0.023	0.023	0.008	0.017
1996	0.000	0.001	0.002	0.005	0.007	0.009	0.012	0.014	0.017	0.025	0.025	0.008	0.015

Year	2	3	4	5	6	7	8	9	10	11	12+	5-8	9+
1997	0.000	0.000	0.002	0.005	0.010	0.011	0.018	0.024	0.035	0.039	0.039	0.010	0.028
1998	0.000	0.000	0.001	0.014	0.021	0.027	0.023	0.035	0.047	0.051	0.051	0.021	0.042
1999	0.000	0.000	0.003	0.009	0.053	0.073	0.072	0.072	0.095	0.133	0.133	0.033	0.091
2000	0.000	0.000	0.002	0.010	0.024	0.080	0.122	0.090	0.146	0.169	0.169	0.032	0.125
2001	0.000	0.000	0.003	0.014	0.042	0.049	0.129	0.142	0.127	0.182	0.182	0.039	0.149
2002	0.000	0.000	0.002	0.016	0.033	0.062	0.059	0.128	0.192	0.126	0.126	0.038	0.145
2003	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.004	0.010	0.020	0.020	0.002	0.007
2004	0.000	0.000	0.000	0.003	0.018	0.034	0.054	0.052	0.058	0.096	0.096	0.020	0.058
2005	0.000	0.000	0.001	0.007	0.027	0.063	0.071	0.096	0.095	0.098	0.098	0.026	0.096
2006	0.000	0.000	0.004	0.014	0.041	0.066	0.065	0.101	0.153	0.113	0.113	0.032	0.117
2007	0.000	0.000	0.000	0.003	0.016	0.044	0.065	0.067	0.075	0.082	0.082	0.022	0.073
2008	0.000	0.000	0.002	0.008	0.025	0.051	0.077	0.067	0.084	0.075	0.075	0.030	0.072
2009	0.000	0.000	0.000	0.001	0.002	0.004	0.006	0.006	0.013	0.011	0.015	0.003	0.009
2010	0.000	0.000	0.000	0.001	0.002	0.004	0.005	0.005	0.008	0.007	0.005	0.002	0.006
2011	0.000	0.000	0.000	0.001	0.001	0.006	0.007	0.011	0.005	0.006	0.005	0.002	0.007
2012	0.000	0.000	0.000	0.001	0.004	0.008	0.012	0.011	0.019	0.008	0.009	0.004	0.012
2013	0.000	0.000	0.000	0.000	0.002	0.003	0.007	0.020	0.019	0.015	0.017	0.002	0.019
2014	0.000	0.000	0.000	0.001	0.002	0.005	0.007	0.009	0.012	0.020	0.021	0.002	0.012

Table 15b: The instantaneous rate of fishing mortality for the southern Gulf of St. Lawrence cod stock from the SCA model (1971-2014).

Year	2	3	4	5	6	7	8	9	10	11	12+	5-8	9+
1971	0.000	0.004	0.064	0.276	0.334	0.337	0.338	0.338	0.338	0.338	0.338	0.311	0.338
1972	0.000	0.006	0.094	0.403	0.488	0.494	0.494	0.494	0.494	0.494	0.494	0.457	0.494
1973	0.000	0.006	0.087	0.375	0.454	0.459	0.460	0.460	0.460	0.460	0.460	0.418	0.460
1974	0.000	0.006	0.095	0.408	0.494	0.500	0.500	0.500	0.500	0.500	0.500	0.464	0.500
1975	0.000	0.005	0.083	0.358	0.433	0.438	0.438	0.438	0.438	0.438	0.438	0.392	0.438
1976	0.000	0.001	0.024	0.243	0.472	0.497	0.499	0.499	0.499	0.499	0.499	0.352	0.499
1977	0.000	0.001	0.013	0.134	0.260	0.274	0.274	0.274	0.274	0.274	0.274	0.195	0.274
1978	0.000	0.001	0.014	0.141	0.274	0.288	0.289	0.289	0.289	0.289	0.289	0.179	0.289
1979	0.000	0.001	0.013	0.134	0.261	0.274	0.275	0.275	0.275	0.275	0.275	0.185	0.275
1980	0.000	0.001	0.011	0.110	0.214	0.225	0.226	0.226	0.226	0.226	0.226	0.157	0.226
1981	0.000	0.001	0.012	0.118	0.230	0.242	0.243	0.243	0.243	0.243	0.243	0.189	0.243
1982	0.000	0.001	0.010	0.104	0.202	0.213	0.213	0.213	0.213	0.213	0.213	0.168	0.213
1983	0.000	0.001	0.012	0.123	0.239	0.252	0.252	0.252	0.252	0.252	0.252	0.201	0.252
1984	0.000	0.001	0.010	0.105	0.204	0.215	0.216	0.216	0.216	0.216	0.216	0.148	0.216
1985	0.000	0.001	0.010	0.107	0.208	0.219	0.220	0.220	0.220	0.220	0.220	0.156	0.220
1986	0.000	0.001	0.011	0.113	0.220	0.232	0.232	0.232	0.232	0.232	0.232	0.189	0.232
1987	0.000	0.001	0.012	0.119	0.232	0.244	0.245	0.245	0.245	0.245	0.245	0.197	0.245
1988	0.000	0.001	0.014	0.144	0.280	0.294	0.295	0.295	0.295	0.295	0.295	0.231	0.295
1989	0.000	0.001	0.019	0.191	0.373	0.392	0.393	0.393	0.393	0.393	0.393	0.303	0.393
1990	0.000	0.001	0.023	0.237	0.461	0.485	0.486	0.486	0.486	0.486	0.486	0.369	0.486
1991	0.000	0.001	0.025	0.256	0.498	0.524	0.526	0.526	0.526	0.526	0.526	0.382	0.526
1992	0.000	0.001	0.024	0.242	0.470	0.495	0.496	0.496	0.496	0.496	0.496	0.345	0.496
1993	0.000	0.000	0.003	0.028	0.055	0.058	0.058	0.058	0.058	0.058	0.058	0.042	0.058
1994	0.000	0.000	0.001	0.002	0.007	0.014	0.019	0.020	0.021	0.021	0.021	0.007	0.021
1995	0.000	0.000	0.000	0.002	0.005	0.010	0.014	0.015	0.015	0.015	0.015	0.006	0.015
1996	0.000	0.000	0.000	0.001	0.005	0.010	0.013	0.014	0.014	0.014	0.014	0.006	0.014

Year	2	3	4	5	6	7	8	9	10	11	12+	5-8	9+
1997	0.000	0.000	0.001	0.002	0.007	0.015	0.020	0.021	0.022	0.022	0.022	0.008	0.022
1998	0.000	0.000	0.001	0.004	0.012	0.024	0.032	0.035	0.035	0.036	0.036	0.014	0.035
1999	0.000	0.001	0.002	0.008	0.026	0.054	0.072	0.079	0.080	0.081	0.081	0.028	0.080
2000	0.000	0.001	0.002	0.010	0.031	0.063	0.084	0.091	0.093	0.094	0.094	0.031	0.093
2001	0.000	0.001	0.003	0.010	0.033	0.069	0.091	0.099	0.101	0.102	0.102	0.035	0.101
2002	0.000	0.001	0.002	0.009	0.029	0.061	0.081	0.088	0.089	0.090	0.090	0.033	0.089
2003	0.000	0.000	0.000	0.000	0.002	0.003	0.004	0.005	0.005	0.005	0.005	0.002	0.005
2004	0.000	0.000	0.001	0.005	0.016	0.034	0.045	0.049	0.050	0.050	0.050	0.018	0.049
2005	0.000	0.000	0.002	0.008	0.024	0.050	0.066	0.072	0.073	0.074	0.074	0.024	0.073
2006	0.000	0.001	0.002	0.009	0.030	0.062	0.083	0.090	0.092	0.092	0.092	0.026	0.091
2007	0.000	0.000	0.001	0.006	0.018	0.036	0.049	0.053	0.054	0.054	0.054	0.019	0.053
2008	0.000	0.000	0.002	0.007	0.022	0.045	0.060	0.065	0.067	0.067	0.067	0.026	0.066
2009	0.000	0.000	0.000	0.001	0.002	0.004	0.006	0.006	0.007	0.007	0.007	0.003	0.007
2010	0.000	0.000	0.000	0.001	0.002	0.004	0.005	0.005	0.005	0.005	0.005	0.002	0.005
2011	0.000	0.000	0.000	0.001	0.002	0.004	0.005	0.006	0.006	0.006	0.006	0.002	0.006
2012	0.000	0.000	0.000	0.001	0.003	0.006	0.008	0.009	0.009	0.009	0.009	0.003	0.009
2013	0.000	0.000	0.000	0.001	0.002	0.005	0.007	0.007	0.007	0.007	0.007	0.002	0.007
2014	0.000	0.000	0.000	0.001	0.002	0.005	0.006	0.007	0.007	0.007	0.007	0.002	0.007

Table 16a: Beginning of the year population abundance (thousands) by age for the southern Gulf of St. Lawrence cod stock from the VPA model (1971-2015).

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+
1971	199759	233997	65382	30943	30921	19298	5929	3656	1722	255	1378	393479	94100
1972	301996	97068	113702	30343	19126	17317	10686	2824	1792	904	564	294326	83556
1973	365779	145024	44480	39823	14344	9853	7561	5660	1388	931	628	269691	80188
1974	344080	172637	67538	16371	19906	7078	4807	3737	2802	600	725	296202	56027
1975	1031420	159402	77993	27729	8982	7750	3059	2302	1368	1259	531	290376	52981
1976	1543450	471260	71800	29831	16580	5107	3423	1336	807	367	547	601057	57998
1977	1610910	697234	212553	29770	15509	7362	2658	1682	604	369	378	968118	58331
1978	1291800	716418	309653	91317	19042	9699	4428	1814	1019	298	363	1154052	127981
1979	1377390	563842	312348	128733	64541	11383	5495	2612	1138	545	284	1090921	214731
1980	1157040	588362	240755	130168	89882	42144	6080	2909	1186	585	286	1102356	273239
1981	2425180	486356	247130	99995	91336	59506	25105	3525	1426	520	451	1015350	281864
1982	3058590	1005360	201558	100064	72883	55619	35670	14464	1750	631	378	1488377	281459
1983	1790460	1257010	412861	81831	69199	49587	32671	21284	8018	858	518	1933838	263967
1984	1746590	724521	508631	166362	58144	43236	28158	18742	10211	3334	761	1562099	328947
1985	1602110	690899	286584	200401	124838	38446	25485	15705	8412	4489	1817	1397076	419593
1986	1476440	617464	266172	109519	144576	80735	22224	14247	7145	3711	3051	1268843	385207
1987	1163060	549835	229868	97049	75803	89130	52754	13328	6753	2736	2638	1119895	340192
1988	1373350	418152	197637	82054	66171	47346	50413	33411	6607	2932	2306	907028	291239

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+
1989	1357560	479075	145804	67971	55852	39082	27106	26768	15196	2652	1886	861393	236514
1990	1131420	466266	164505	49153	43936	29904	19235	13436	10129	5142	1429	803133	172362
1991	662769	393033	161668	55477	28664	22400	12808	7899	4403	2440	1837	690629	135928
1992	644936	236973	140370	54856	30496	12307	8872	5135	2100	1180	1166	493454	116111
1993	478825	239681	87783	50161	28255	13302	4333	3411	1308	491	550	429274	101810
1994	392789	183896	92019	33557	34702	18992	8613	2647	1612	584	430	377052	101136
1995	246739	155609	72838	36423	23786	24505	13272	5995	1289	795	489	335002	106554
1996	653692	100300	63213	29527	25959	16923	17359	9391	2917	620	620	266828	103315
1997	522347	271387	41617	26194	21110	18533	12054	12328	4483	1389	585	409679	96675
1998	399765	220530	114566	17538	18662	14968	13128	8483	5753	2070	907	416604	81508
1999	355043	171121	94367	48995	12282	12982	10352	9115	3897	2612	1346	367069	101582
2000	257888	151524	73008	40150	34167	8195	8487	6776	4042	1688	1652	329689	105157
2001	352385	109507	64324	30936	27598	23164	5253	5215	2895	1634	1318	271843	98013
2002	408070	149371	46403	27195	20846	18089	15077	3157	2029	1144	1104	284417	88642
2003	505605	172578	63157	19584	17865	13463	11350	9480	1197	722	855	310251	74516
2004	237509	212266	72451	26512	12505	11401	8585	7231	4049	508	662	356169	71452
2005	295014	98173	87736	29936	16162	7507	6742	4973	2929	1629	454	256240	70331
2006	156381	120701	40162	35870	17639	9337	4183	3727	1910	1125	798	235452	74589
2007	309522	64129	49496	16402	20672	9894	5110	2291	1439	700	733	170866	57241

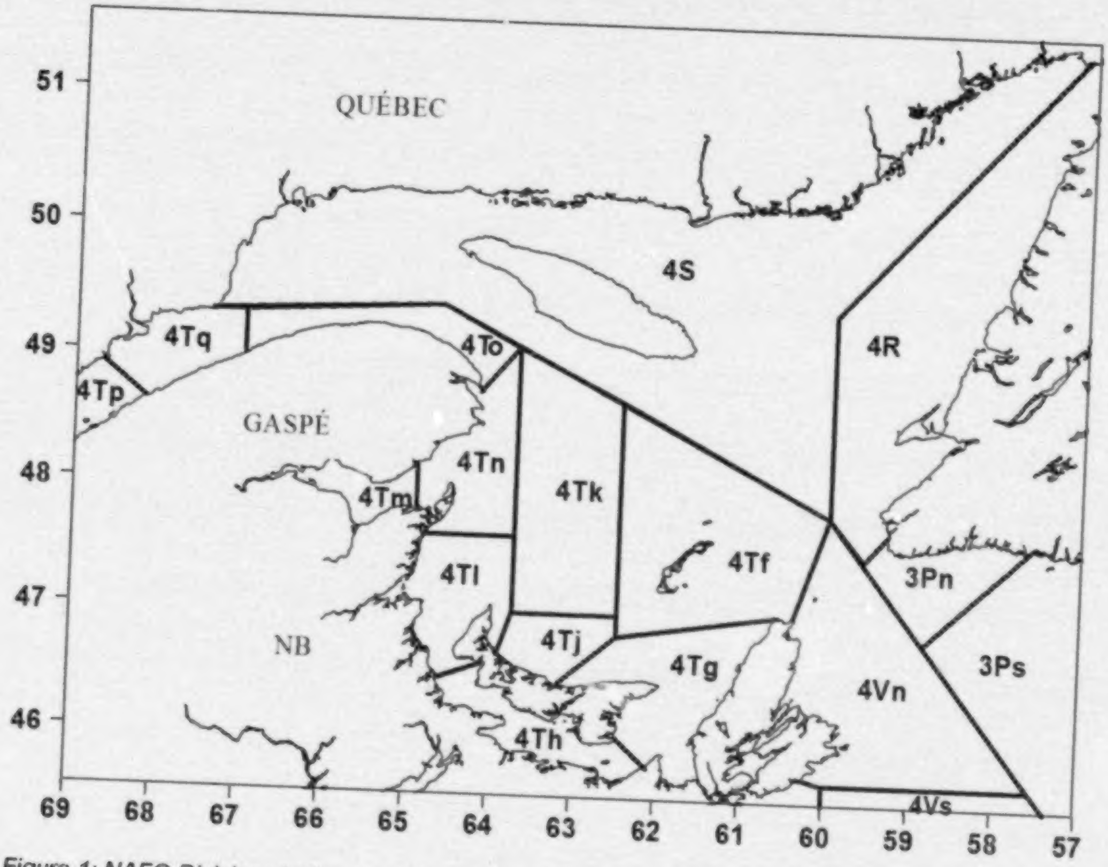
Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+
2008	206447	127528	26418	20385	9325	11602	5402	2732	933	582	575	205483	51536
2009	138894	84435	52156	10784	11091	4989	6044	2744	1126	378	473	174220	37629
2010	247622	56707	34470	21291	5623	5776	2592	3135	1187	484	366	131630	40453
2011	185417	101097	23151	14071	10738	2831	2903	1302	1329	502	360	158285	34037
2012	294182	76815	41882	9589	7066	5388	1415	1449	545	560	363	145072	26376
2013	600797	124249	32442	17685	4865	3573	2717	710	619	231	395	187487	30796
2014	249527	256271	52998	13837	9073	2492	1828	1384	307	268	272	338731	29462
2015	–	106266	109141	22568	7086	4644	1271	931	606	134	233	252881	37474

Table 16b: Beginning of the year population abundance (thousands) by age for the southern Gulf of St. Lawrence cod stock from the SCA model, 1971 to 2014.

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+
1971	100976	110917	65309	45560	35270	23285	7338	3423	2421	969	1526	296017	119791
1972	159171	65464	71631	39726	27891	20372	13399	4222	1724	1219	1256	246904	109809
1973	162779	101907	41675	41775	21278	13721	9967	6554	1822	744	1068	240511	96929
1974	158053	102724	63970	24114	22797	10729	6883	4999	2945	819	814	240794	74100
1975	436688	99207	64108	36534	12562	10897	5100	3271	2165	1275	707	235826	72511
1976	529664	277060	62626	37443	19688	6278	5419	2536	1509	999	915	414472	74786
1977	650960	343017	179206	39610	22225	9288	2889	2491	1100	655	830	601311	79088
1978	450881	429625	226233	116744	25914	12814	5283	1642	1340	592	799	820985	165127
1979	391879	301146	286744	149046	75563	14683	7157	2948	856	698	724	839566	251676
1980	315393	262850	201853	189837	97030	43336	8307	4046	1526	443	736	809964	345261
1981	620125	213057	177463	134905	125939	58012	25621	4908	2153	812	628	743497	352977
1982	676714	422271	144993	119460	87895	73372	33393	14738	2522	1106	740	900490	333226
1983	349262	466517	290953	98949	77618	51762	42754	19447	7680	1314	962	1057956	300486
1984	355350	241901	322910	199119	62724	43803	28848	23811	9478	3743	1109	937446	372635
1985	351725	244801	166557	220189	129020	36799	25425	16734	11633	4630	2370	858158	446800
1986	304638	238799	166114	111908	142896	75666	21347	14740	7938	5518	3321	788248	383335
1987	274071	203147	159150	109558	72131	82751	43316	12213	6760	3641	4054	696721	334424
1988	275028	180642	133814	103686	69265	40742	46176	24154	5498	3043	3464	610483	296027

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+
1989	301893	179265	117658	86008	62758	36591	21210	24019	10370	2360	2794	543032	246109
1990	250407	196869	116787	75309	48637	29611	16931	9803	9251	3994	1985	509178	195522
1991	172991	164199	128937	74834	40039	20668	12282	7013	3383	3193	2063	456612	163476
1992	155262	114035	108098	82902	38674	16241	8167	4847	2290	1104	1716	378074	155941
1993	141726	103270	75755	70227	42972	15949	6535	3282	1623	767	945	321324	142299
1994	146831	94971	69192	50623	44800	26684	9875	4045	1706	844	890	303630	139468
1995	98952	99952	64643	47076	32874	28955	17121	6306	2173	916	931	300948	136353
1996	151095	68098	68781	44470	30593	21290	18654	10992	3381	1165	990	268414	131535
1997	146941	105136	47381	47843	28800	19750	13677	11945	5890	1811	1154	283387	130870
1998	125511	102776	73528	33122	30799	18449	12556	8652	6383	3146	1584	290996	114691
1999	115416	88155	72175	51599	21115	19477	11524	7780	4576	3373	2499	282273	121943
2000	76355	81117	61934	50626	32647	13120	11769	6838	3922	2303	2954	267228	124177
2001	93347	54040	57384	43732	31697	20015	7786	6839	3303	1891	2533	229220	117796
2002	99822	66691	38589	40895	26755	18954	11553	4393	3171	1529	2046	214576	109296
2003	129537	71693	47877	27654	24384	15635	10735	6412	2013	1450	1634	209487	89917
2004	65968	92772	51344	34285	16203	14272	9135	6266	3160	992	1520	229949	85832
2005	64687	46710	65674	36311	19891	9295	8046	5092	2890	1456	1157	196521	84137
2006	39470	45602	32917	46214	20881	11251	5125	4363	2174	1232	1113	170871	92352
2007	67836	27900	32220	23215	25851	11441	5970	2664	1765	878	946	132851	72731

Year	2	3	4	5	6	7	8	9	10	11	12+	3+	5+
2008	60120	48462	19927	22987	12490	13741	5968	3077	1076	712	736	129176	60787
2009	43760	43002	34652	14230	11995	6420	6900	2952	1213	424	570	122358	44704
2010	63165	31258	30716	24748	7303	6147	3283	3523	1232	506	415	109132	47158
2011	54340	44953	22245	21857	12741	3755	3155	1683	1461	511	382	112742	45544
2012	71158	38642	31966	15817	11006	6407	1885	1581	730	633	387	109052	38444
2013	108627	50733	27549	22785	7673	5328	3092	907	725	335	468	119595	41313
2014	56411	77776	36323	19721	10841	3645	2524	1462	425	340	376	153435	39335


51
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QUÉBEC
GASPÉ
NB
4S
4R
4Tq
4Tp
4To
4Tn
4Tm
4Tk
4Tl
4Tf
4Tj
4Tg
4Th
3Pn
3Ps
4Vn
4Vs

Figure 1: NAFO Divisions in the area of the Gulf of St. Lawrence. Unit areas are indicated for Division 4T.

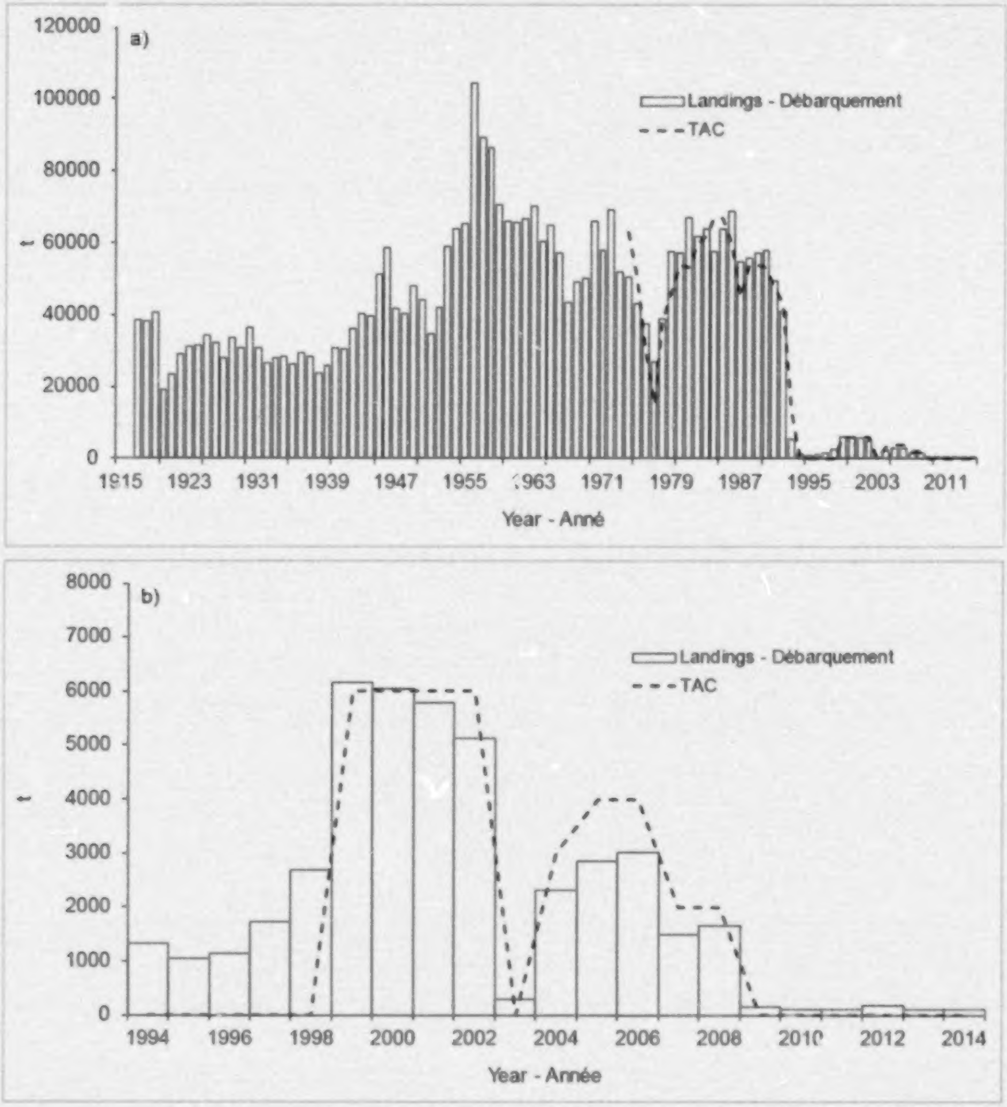


Figure 2: Landings (t) and Total Allowable Catch (t) of southern Gulf of St. Lawrence (4T-Vn (November-April)) Atlantic cod, 1917 to 2014 (upper panel a). The lower panel (b) shows the values for 1994 to 2014.

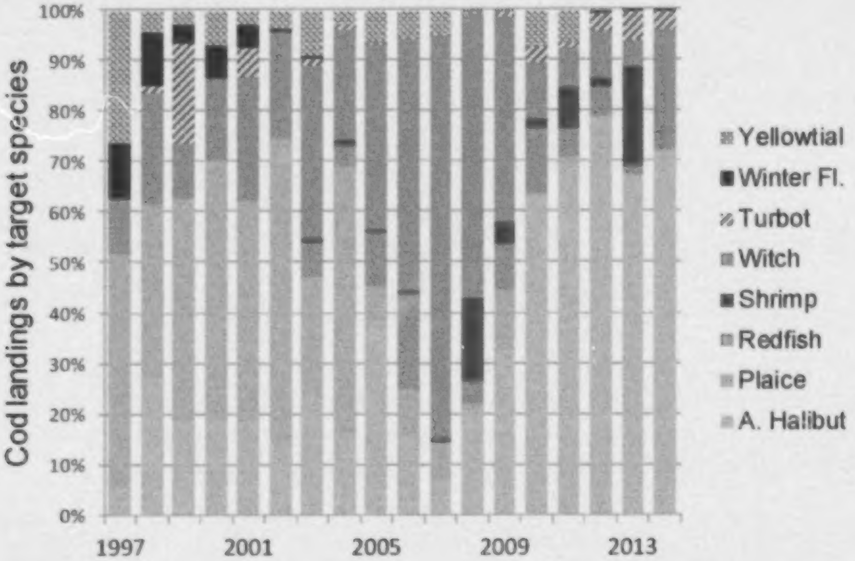


Figure 3: Landings of Atlantic cod by-catch in fisheries targetting other species, 1997 to 2014.

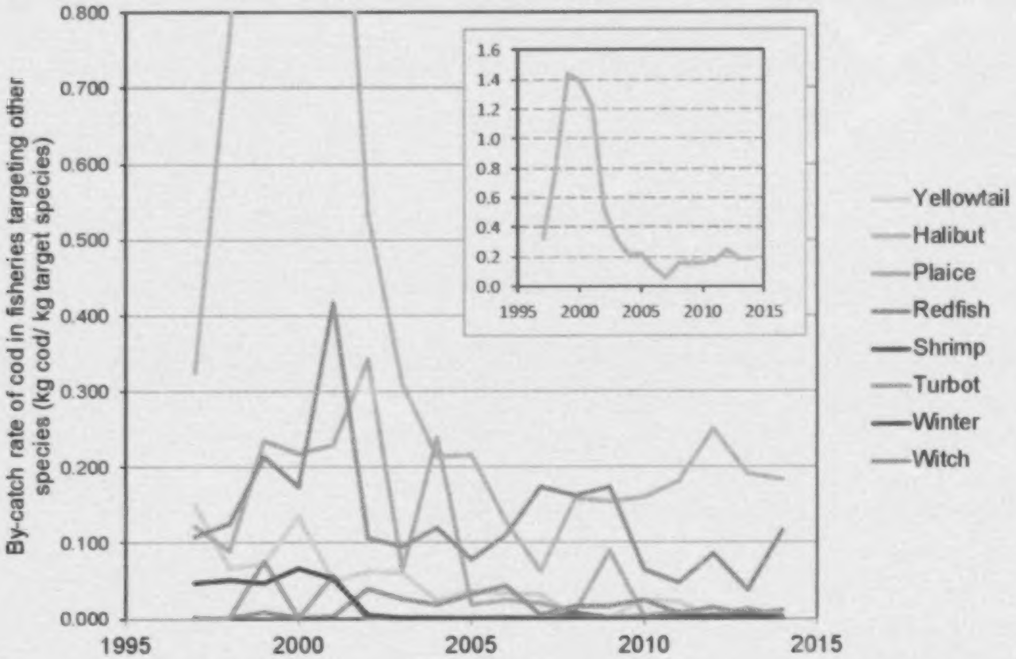


Figure 4: By-catch rates of cod in fisheries targeting other species, 1997 to 2014. Except for shrimp, by-catch rates are estimated as the kg of cod divided by the kg of the target species in the reported landings. For shrimp, rates are based on observer data.The inset shows the bycatch rate in the halibut fishery.

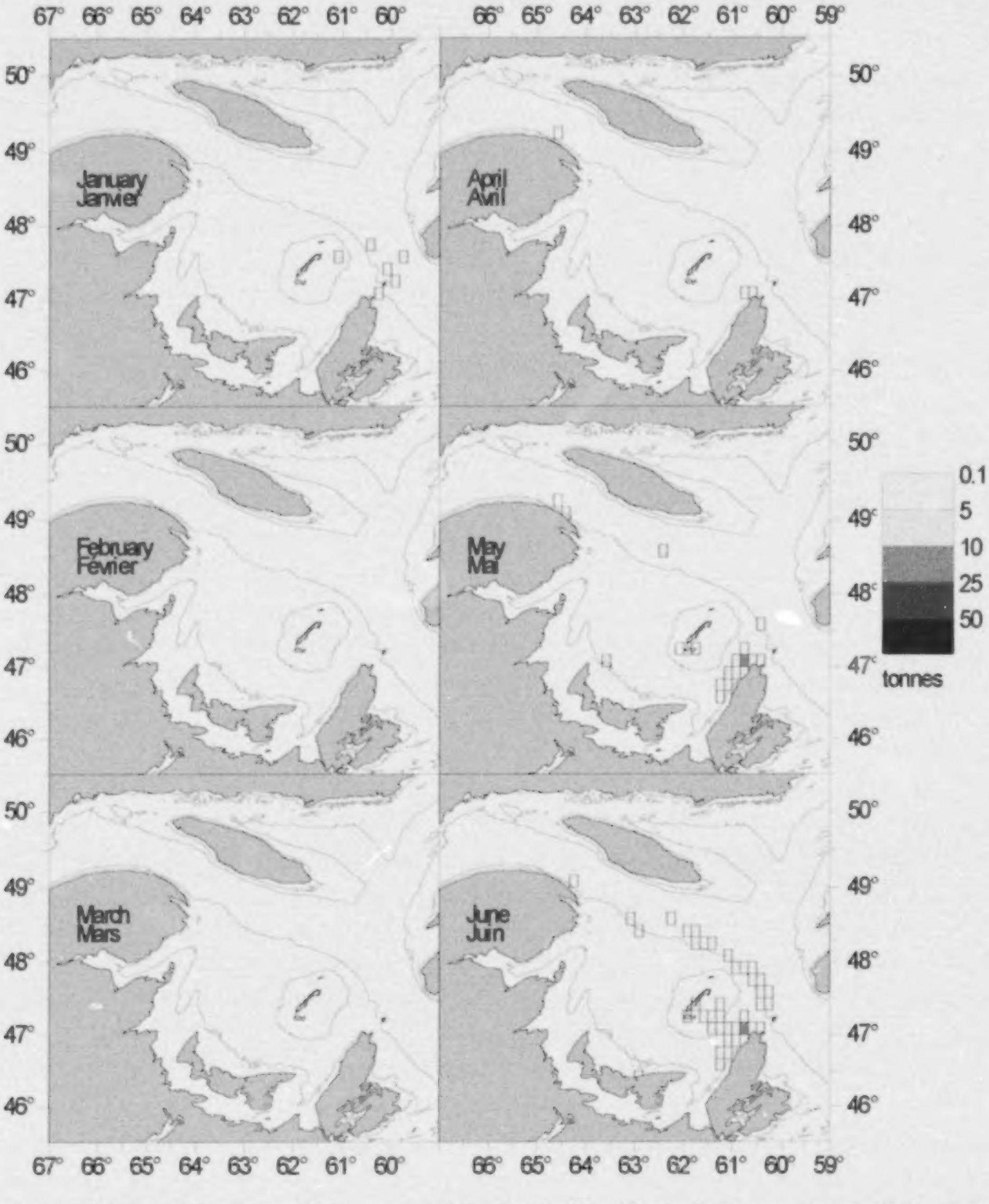
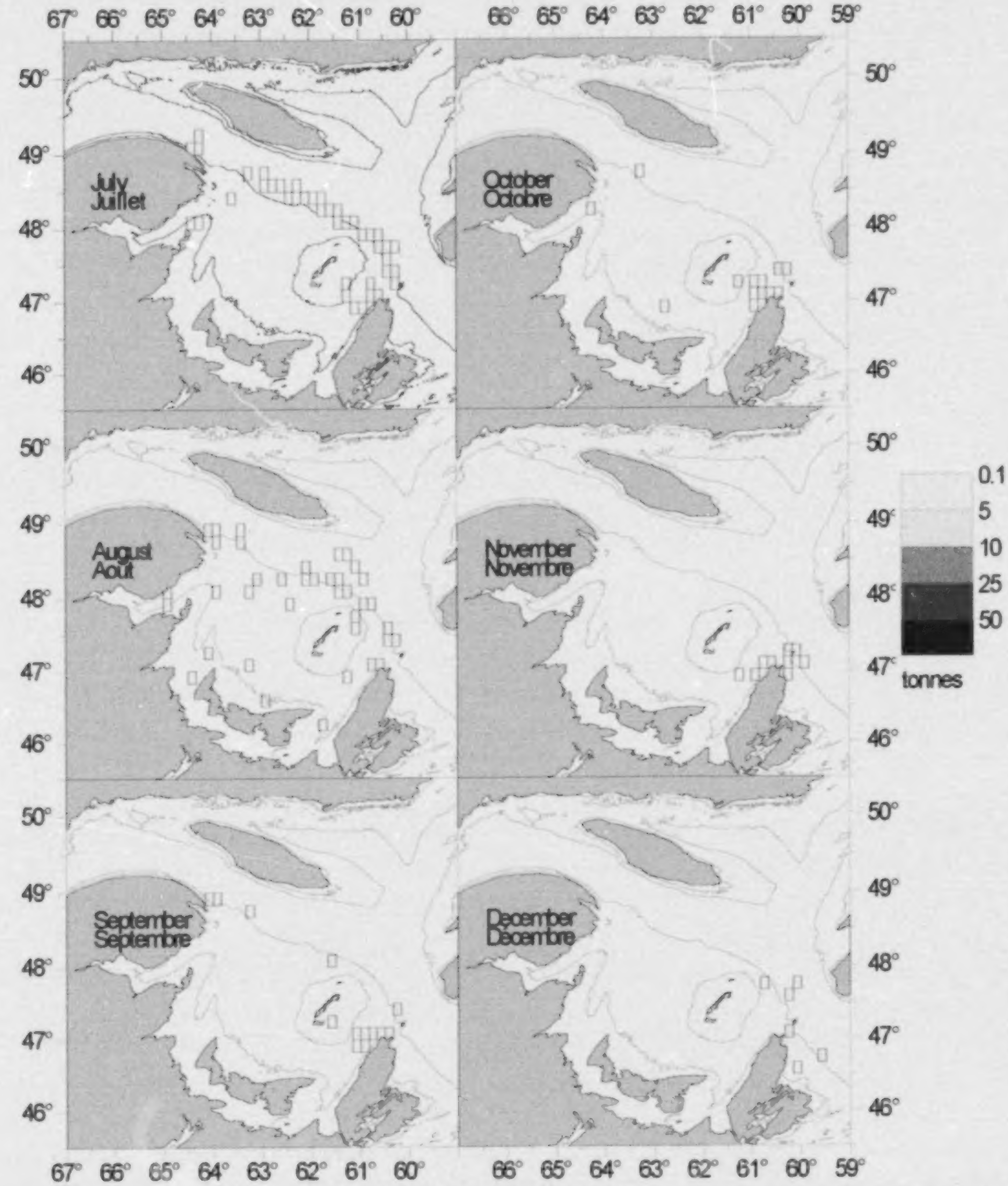

67° 66° 65° 64° 63° 62° 61° 60°
66° 65° 64° 63° 62° 61° 60° 59°
50°
49°
48°
47°
46°
January
Janvier
February
Février
March
Mars
April
Avril
May
Mai
June
Juin
0.1
5
10
25
50
tonnes

Figure 5: Catches (t) of cod by mobile commercial gears in 10 x 10 minute squares by month for January to June, 2009 to 2014.



July
Juillet
October
Octobre
August
Août
November
Novembre
September
Septembre
December
Décembre
0.1
5
10
25
50
tonnes
67° 66° 65° 64° 63° 62° 61° 60°
66° 65° 64° 63° 62° 61° 60° 59°
50° 49° 48° 47° 46°

Figure 6: Catches (t) of Atlantic cod by mobile commercial gears by month in 10 x 10 minute squares by month for July to December, 2009 to 2014.

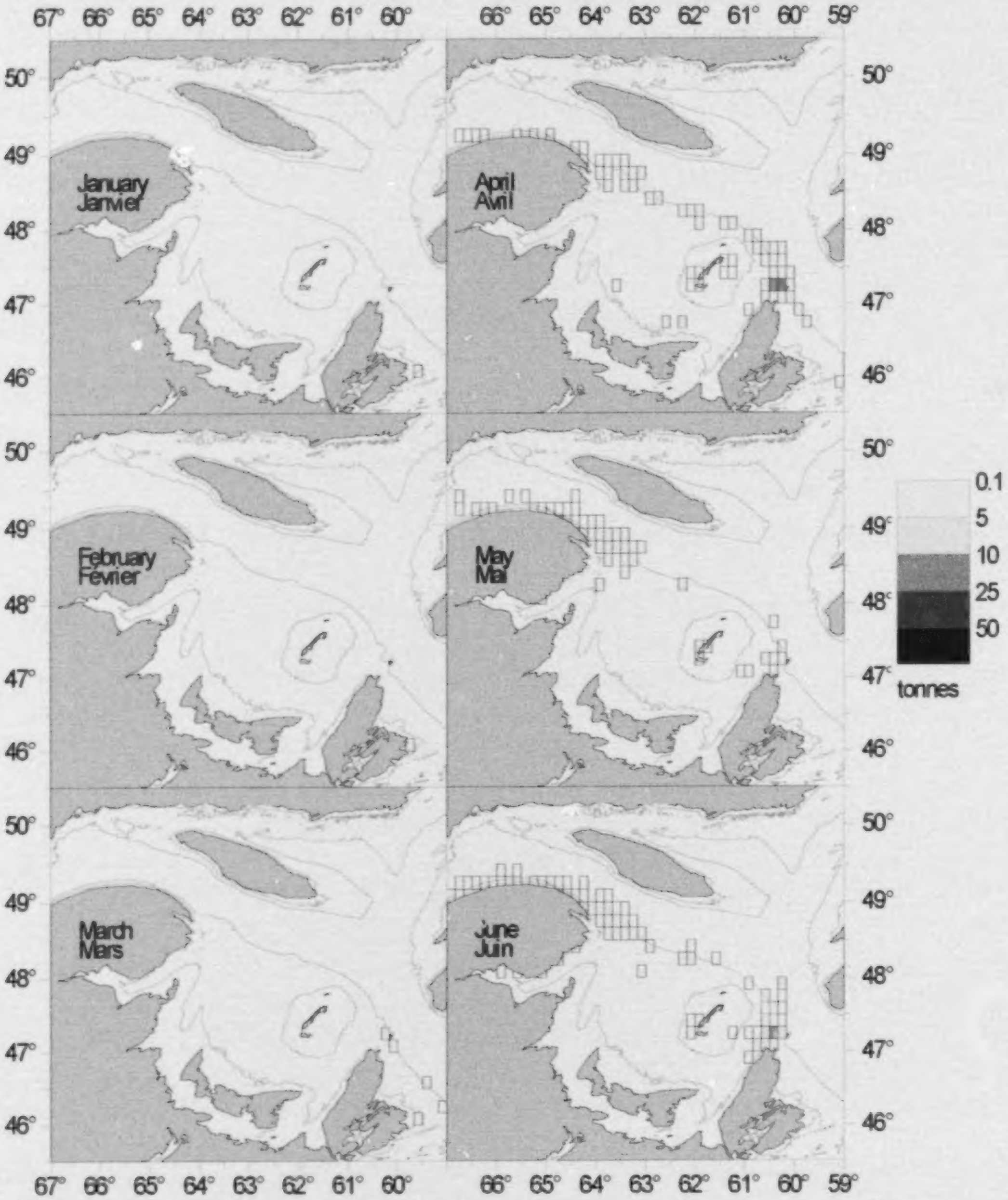

67° 66° 65° 64° 63° 62° 61° 60°
66° 65° 64° 63° 62° 61° 60° 59°
50° 49° 48° 47° 46°
January Janvier
February Fevrier
March Mars
April Avril
May Mai
June Juin
0.1
5
10
25
50
tonnes

Figure 7: Catches (t) of cod by fixed commercial gears by 10 x 10 minute squares and by month, January to June, 2009 to 2014.

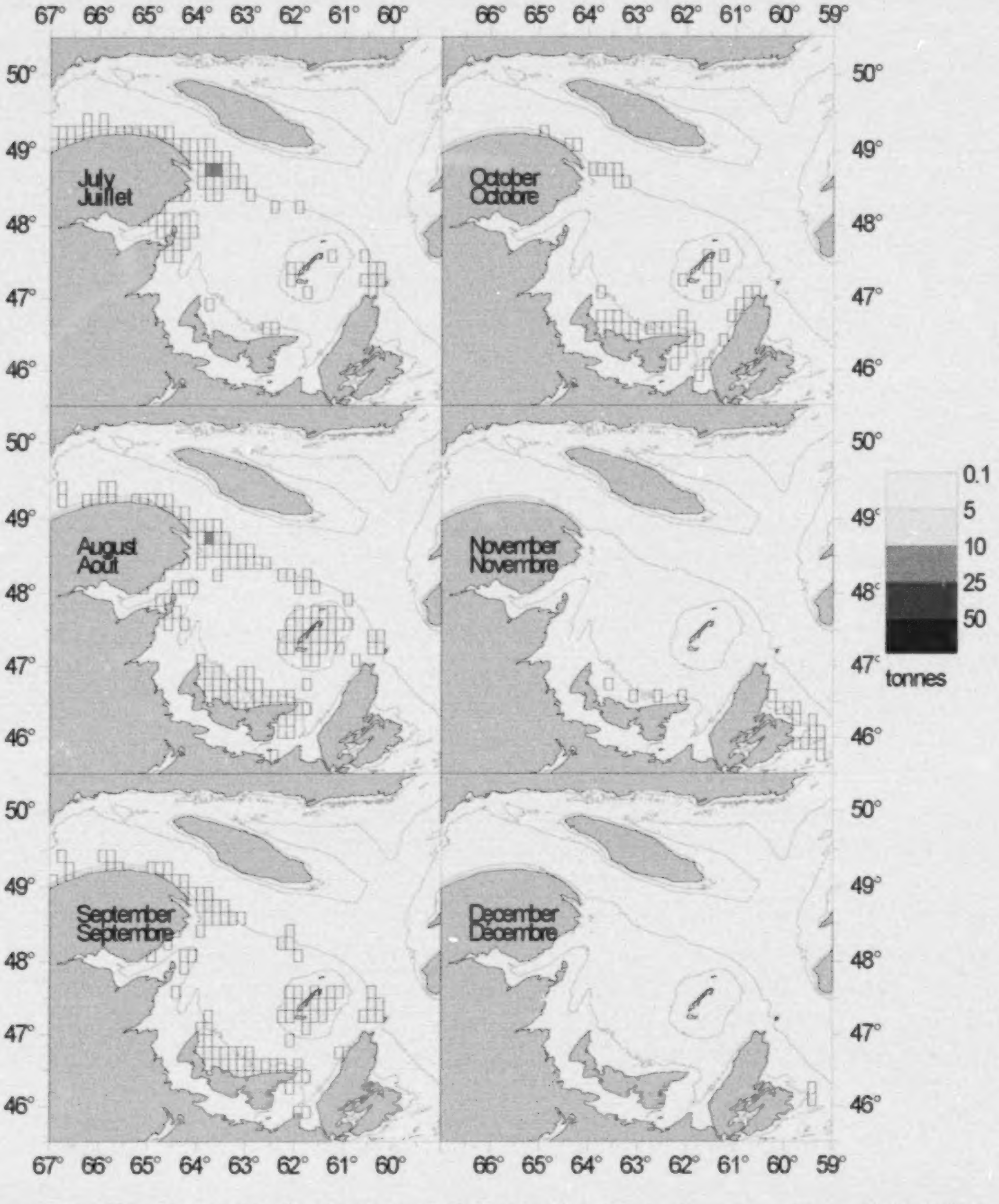

67° 66° 65° 64° 63° 62° 61° 60°
66° 65° 64° 63° 62° 61° 60° 59°
50°
49°
48°
47°
46°
July
Juillet
October
Octobre
August
Août
November
Novembre
September
Septembre
December
Décembre
0.1
5
10
25
50
tonnes

Figure 8: Catches (t) of cod by fixed commercial gears in 10 x 10 minute squares by month for July to December, 2009 to 2014. Catches in the longline sentinel fishery are not included.

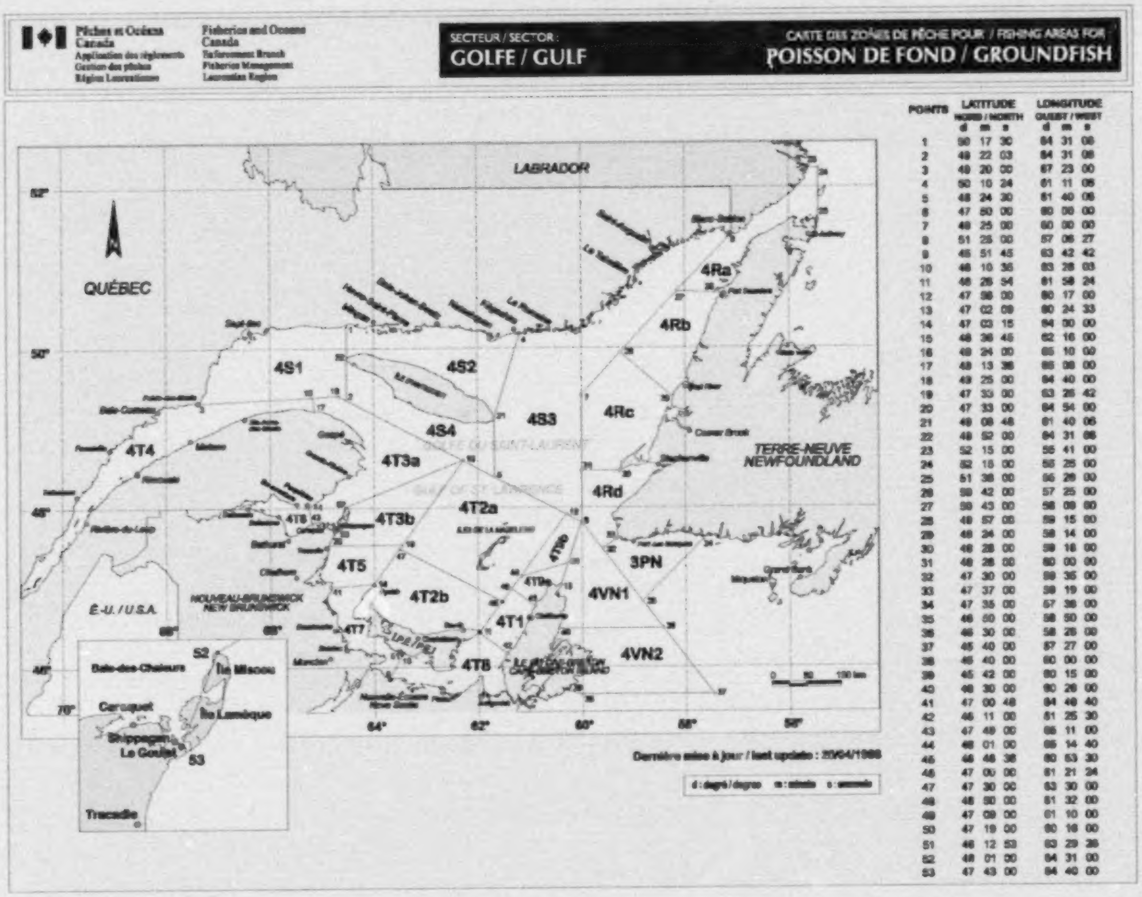
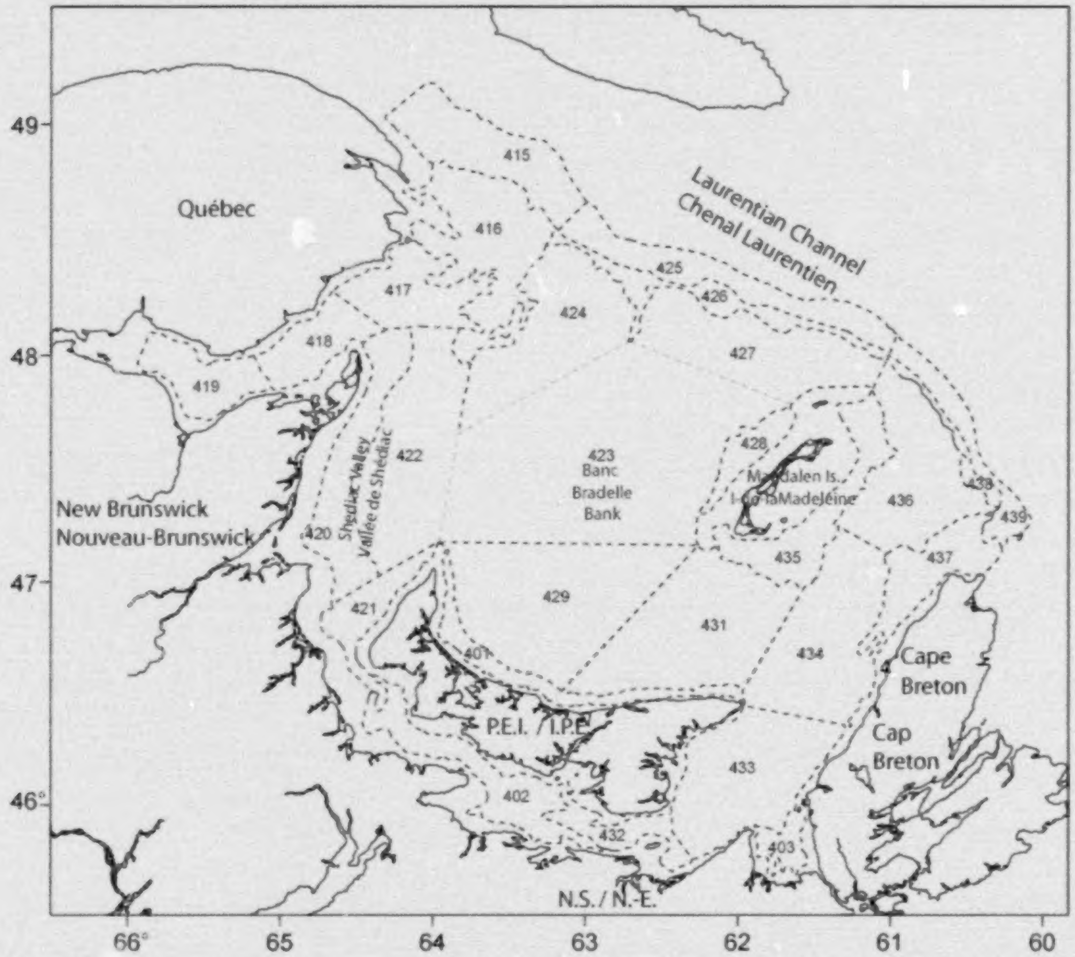

Pêches et Océans Canada
Fisheries and Oceans Canada
SECTEUR / SECTOR : GOLFE / GULF
CARTE DES ZONES DE PÊCHE POUR / FISHING AREAS FOR
POISSON DE FOND / GROUNDFISH
POINTS
LATITUDE NORD / NORTH
LONGITUDE OUEST / WEST
LABRADOR
QUÉBEC
TERRE-NEUVE NEWFOUNDLAND
NOUVEAU-BRUNSWICK NEW BRUNSWICK
É.-U. / U.S.A.
4S1
4S2
4S3
4S4
4Ra
4Rb
4Rc
4Rd
4T3a
4T3b
4T2a
4T2b
4T4
4T5
4T6
4T7
4T8
4T1
3PN
4VN1
4VN2
Baie-des-Chaleurs
Île Miscou
Caraquet
Île Lamèque
Shippagan
Le Goulet
Tracadie
Dernière mise à jour / last update

Figure 9: Groundfish fishing management zones in NAFO Division 4T.


Québec
New Brunswick
Nouveau-Brunswick
Laurentian Channel
Chenal Laurentien
Shediac Valley
Vallée de Shédiac
423
Banc
Bradelle
Bank
Magdalen Is.
I-de-la-Madeleine
Cape
Breton
Cap
Breton
P.E.I. / I.P.E.
N.S. / N.-E.
401
402
403
415
416
417
418
419
420
421
422
424
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427
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429
431
432
433
434
435
436
437
438
439
49
48
47
46°
66°
65
64
63
62
61
60

Figure 10: Stratification scheme for the southern Gulf of St. Lawrence September trawl survey. Strata depths are as follows: < 50 fathoms: 401-403, 417-424, 427-436; 51-100 fathoms: 416, 426, 437-438; >100 fathoms: 415, 425, 439.

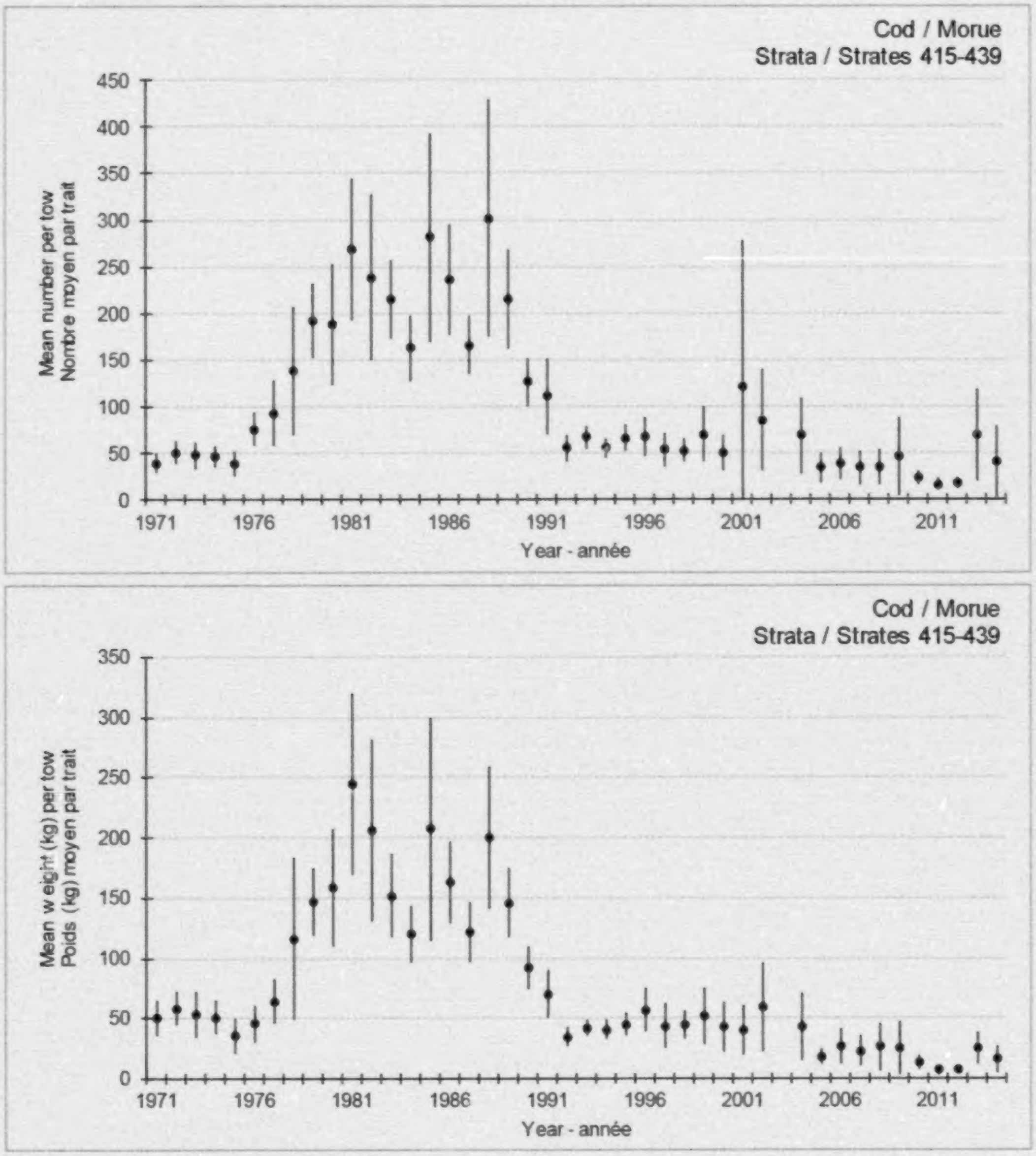


Figure 11: Annual mean catch indices (number per tow, top panel; weight per tow, bottom panel) of cod in the southern Gulf of St. Lawrence September bottom-trawl surveys. Vertical lines denote approximate 95% confidence limits (± 2 standard errors).

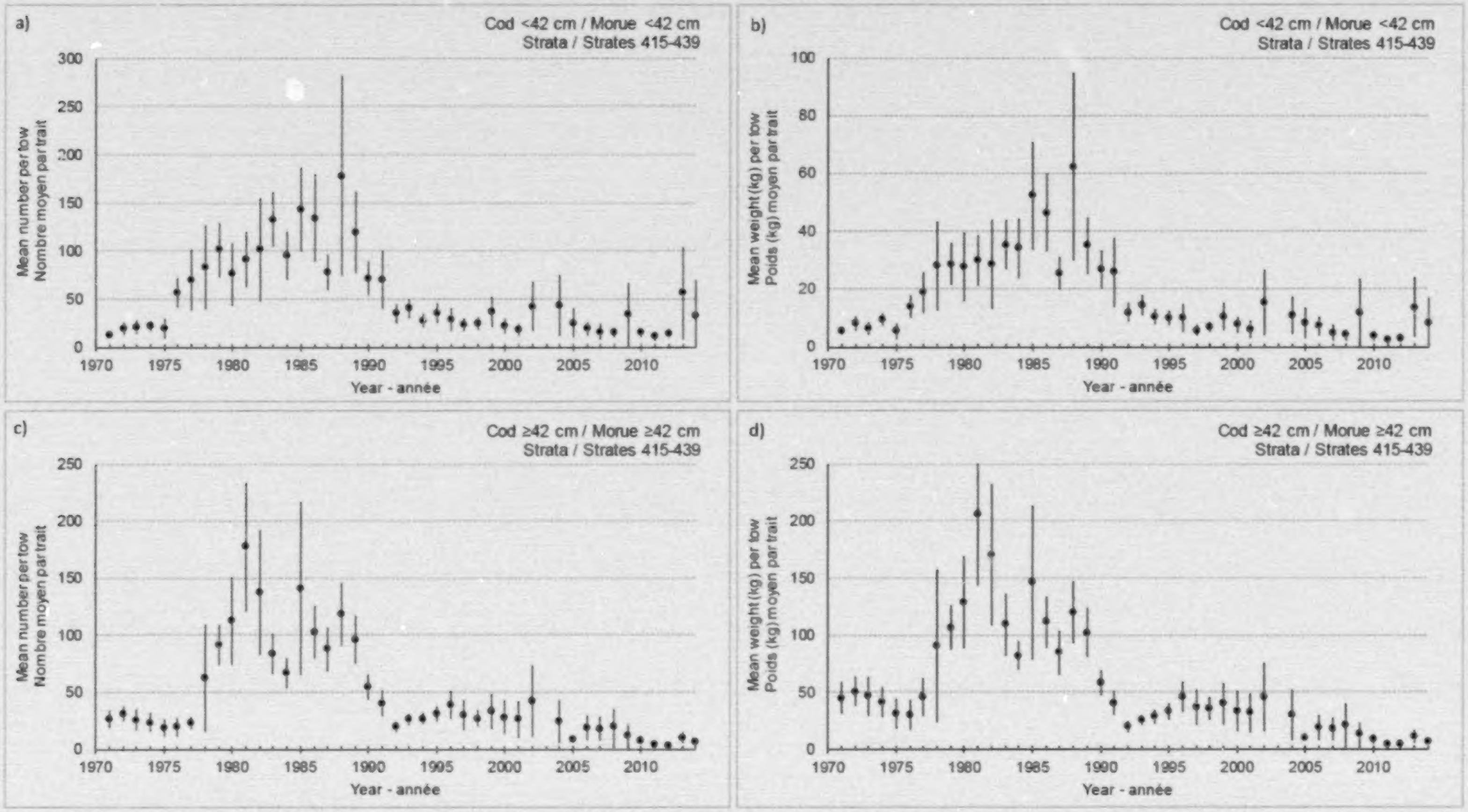


Figure 12: Mean annual catch indices (number per two, left column; weight per tow, right column) of cod <42 cm in length (top row) and ≥42 cm (bottom row) in the southern Gulf of St. Lawrence September bottom-trawl surveys. Vertical lines denote approximate 95% confidence limits (± 2 standard errors).

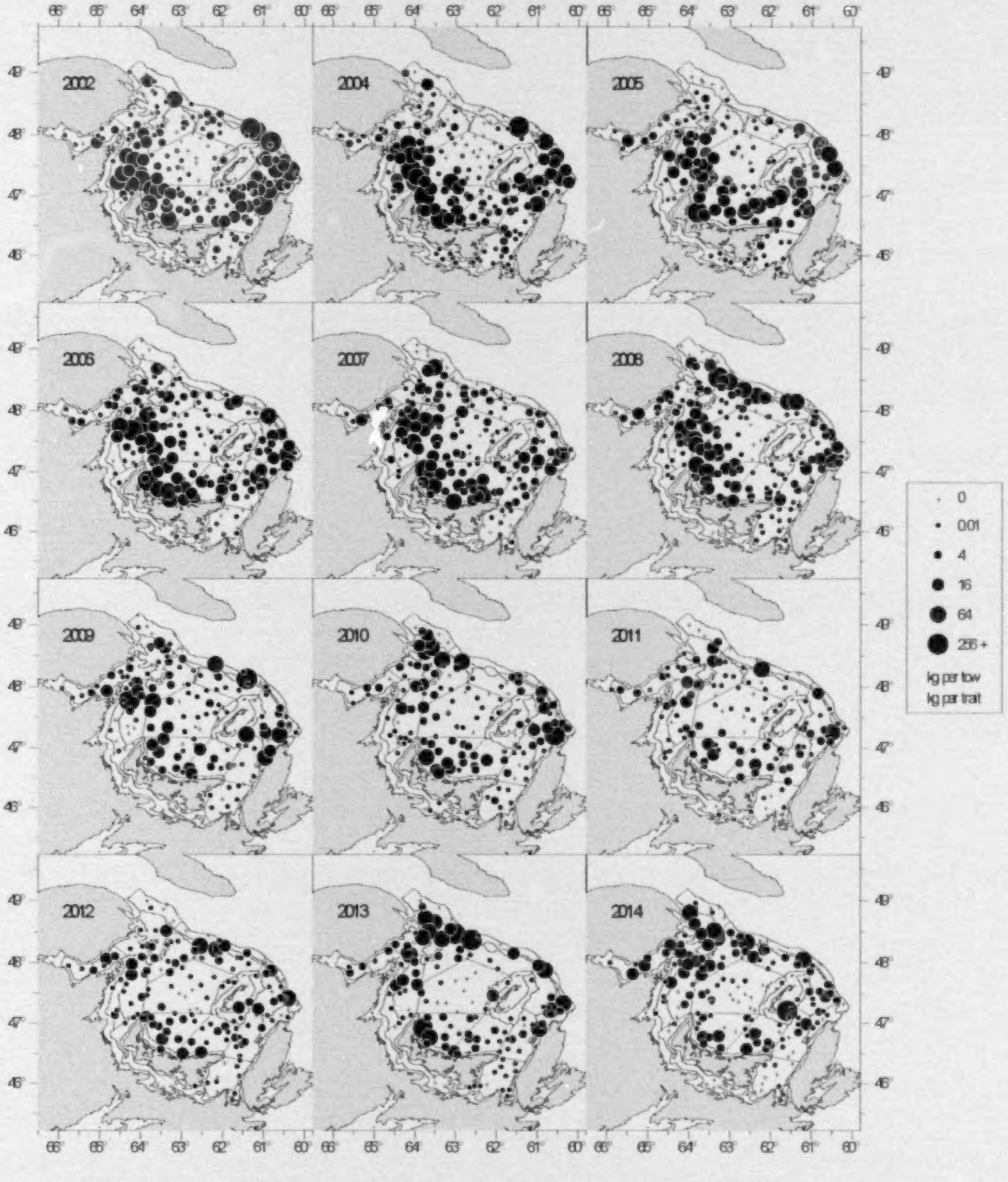

2002
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
66°
65°
64°
63°
62°
61°
60°
49°
48°
47°
46°
0
0.01
4
16
64
256 +
kg per tow
kg par trait

Figure 13: Individual set Atlantic cod catches (kg per tow) in the southern Gulf of St. Lawrence September bottom-trawl surveys from 2002 to 2014. Grey circles are from the Alfred Needler and the black circles are from the Teleost.

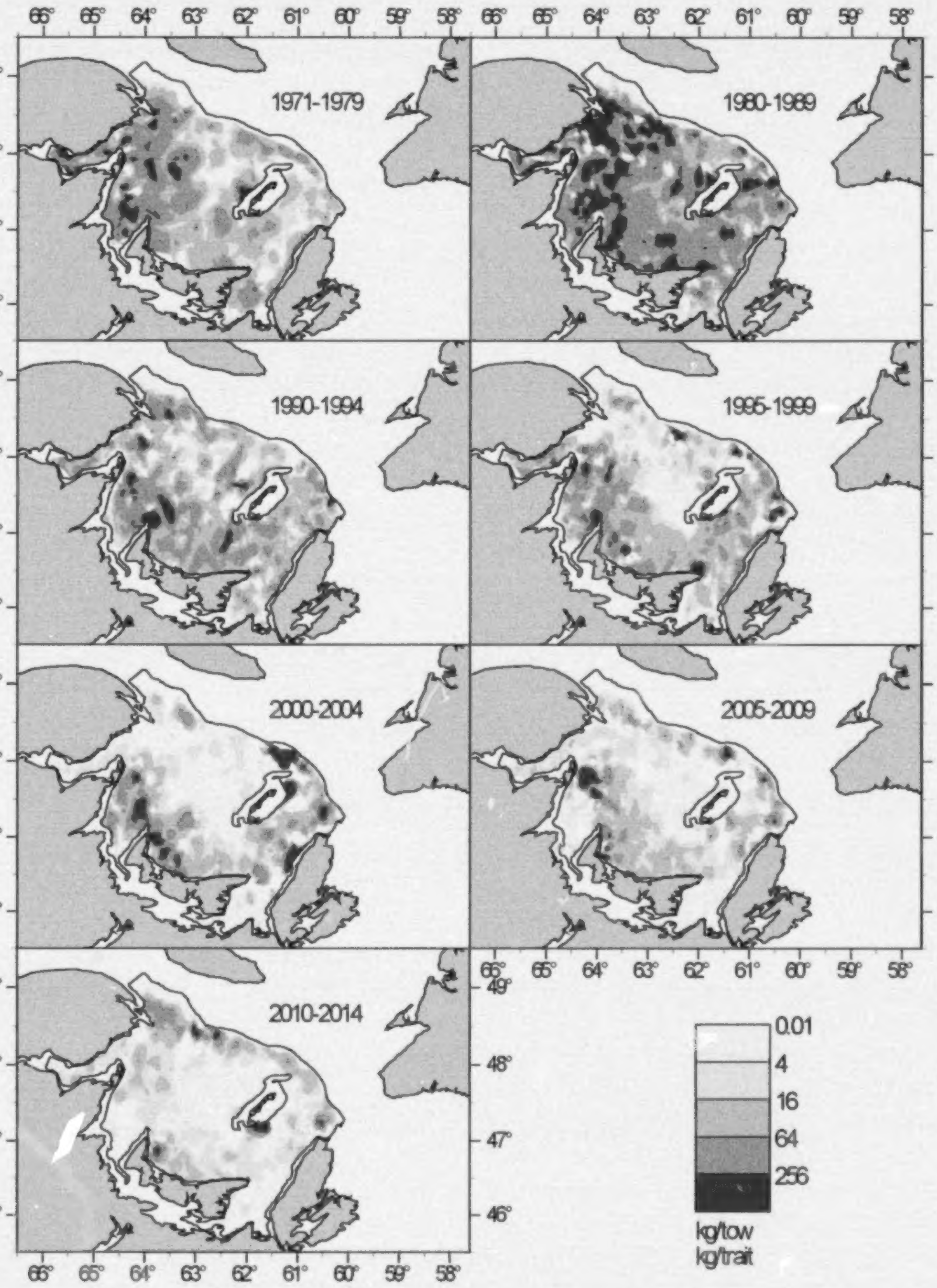

66°
65°
64°
63°
62°
61°
60°
59°
58°
49°
48°
47°
46°
1971-1979
1980-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
0.01
4
16
64
256
kg/tow
kg/trait

Figure 14: Spatial distribution of cod catches by blocks of years in the southern Gulf of St. Lawrence based on September bottom-trawl surveys, 1971 to 2014.

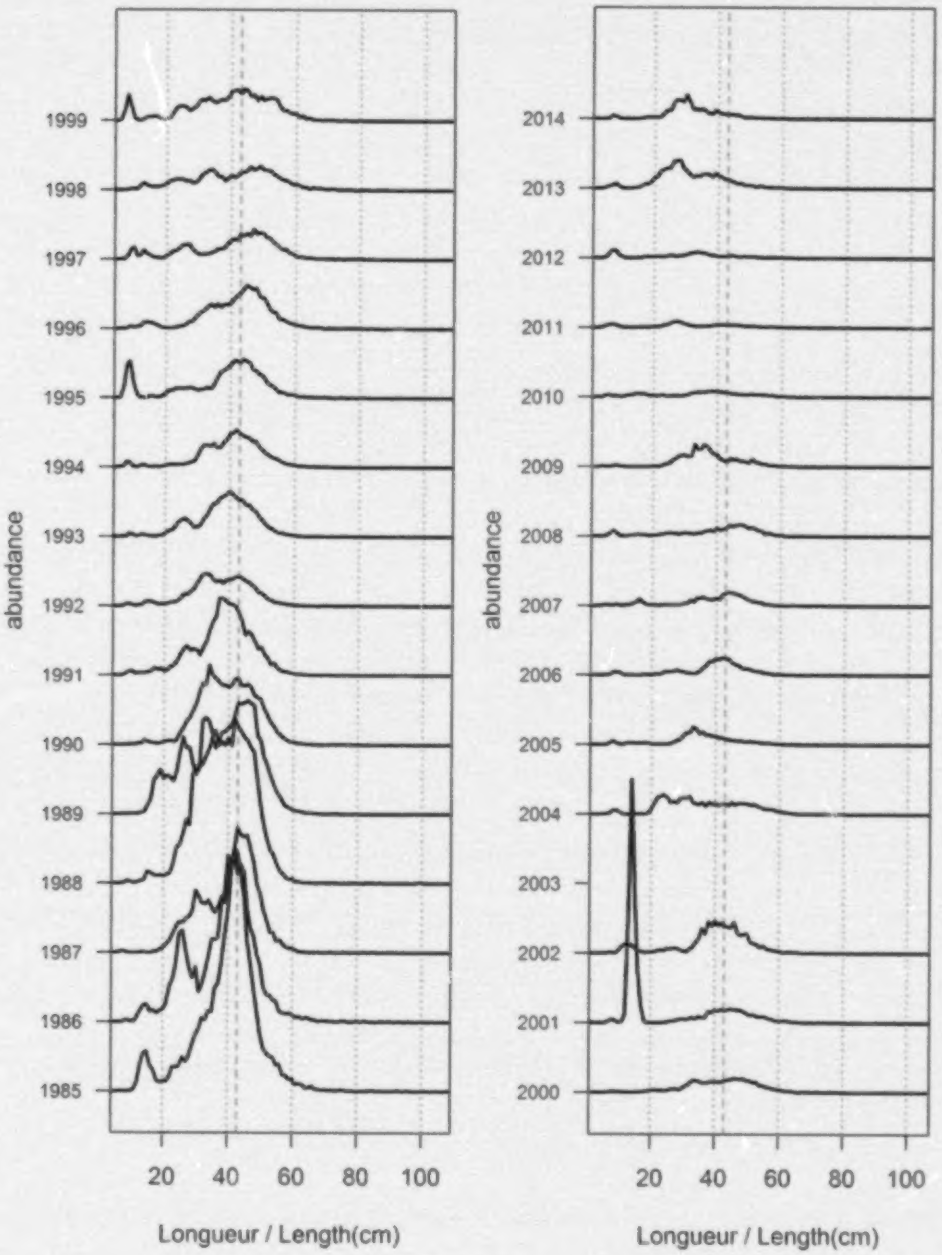


Figure 15: Stratified abundance (mean number per tow) at length for Atlantic cod in in the southern Gulf of St. Lawrence from the September bottom-trawl surveys, 1985 to 2014. The red dotted vertical line indicates the regulated minimum size in the commercial fishery (43 cm).

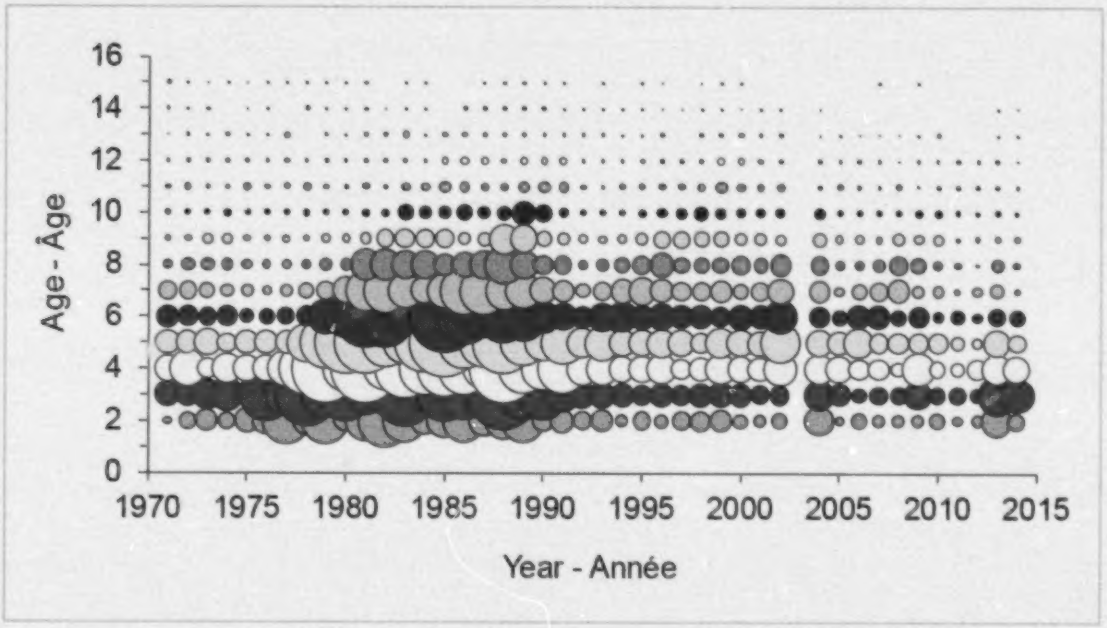


Figure 16: Indices of relative abundance (numbers per tow at age) for Atlantic cod from the southern Gulf of St. Lawrence September trawl survey, 1971-2014. Circle area is proportional to catch rate at age (details in Table 15).

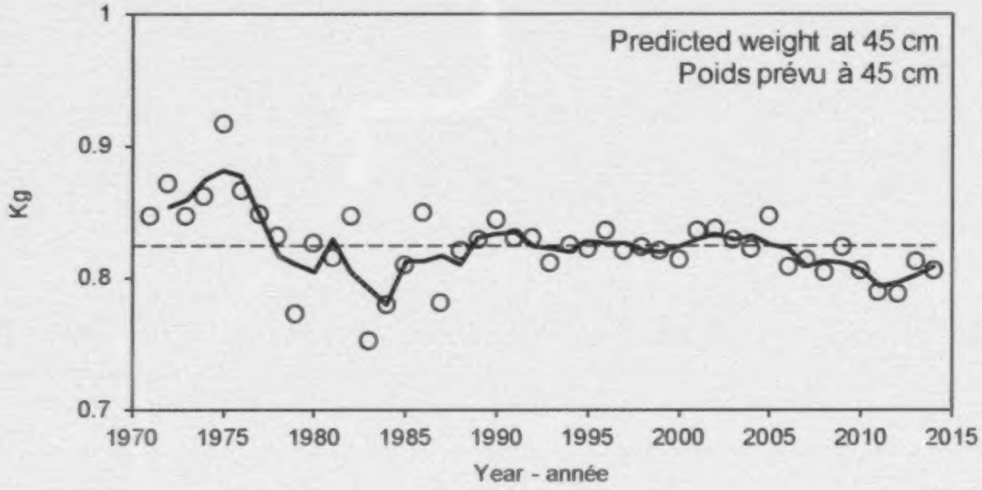


Figure 17: Condition indices, predicted weight for a 45 cm Atlantic cod, based on annual length-weight relationships derived from length and weight data collected during the September trawl surveys in the southern Gulf of St. Lawrence, 1971 to 2014.

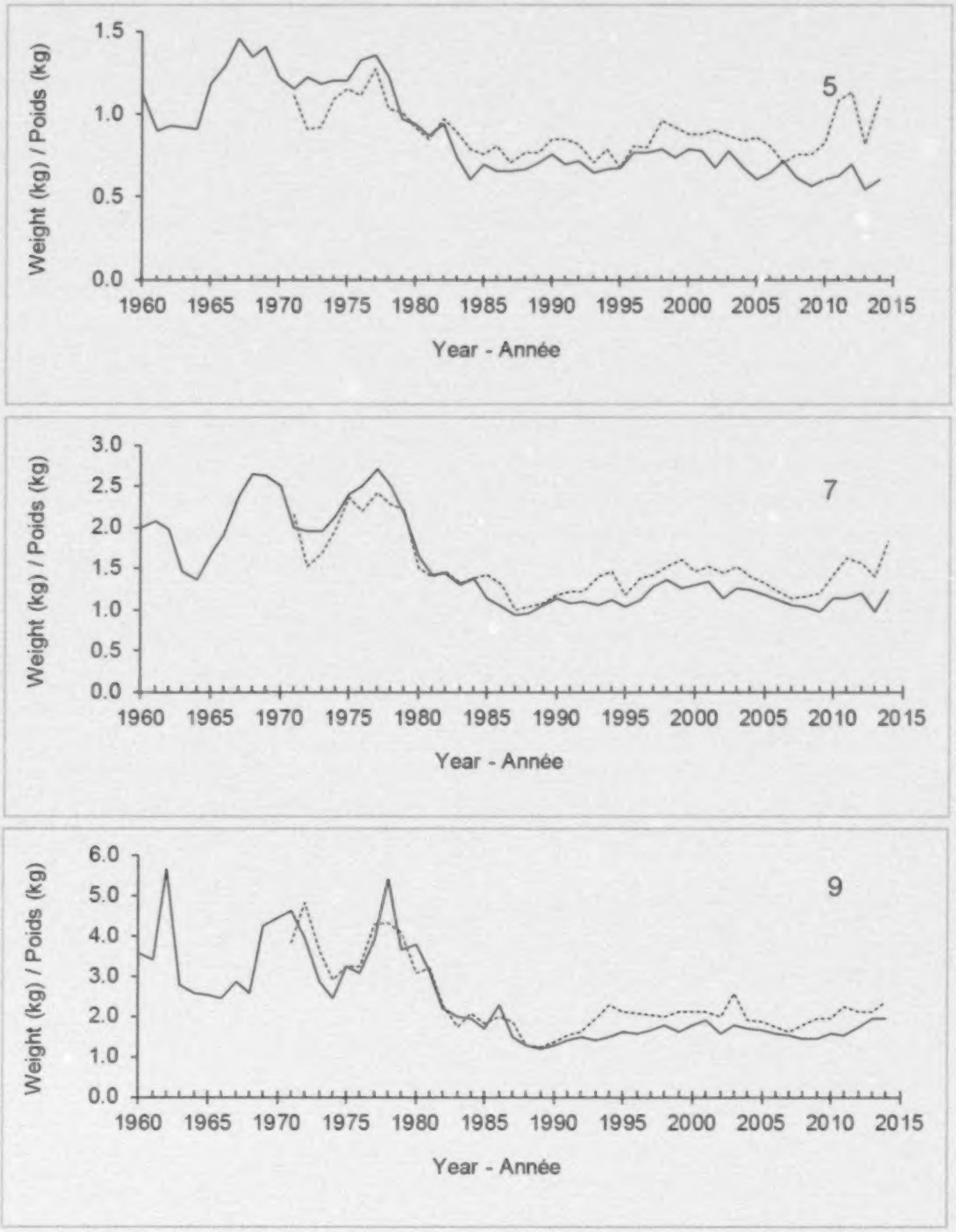


Figure 18: Trends in mean weights (kg) at ages 5 (upper), 7 (middle), and 9 (lower) years of southern Gulf of St. Lawrence Atlantic cod from the research vessel survey (solid lines), 1960 to 2014, and the commercial fishery (dashed lines), 1971 to 2014. Data from 1960 to 1970 are from non-stratified-random surveys.

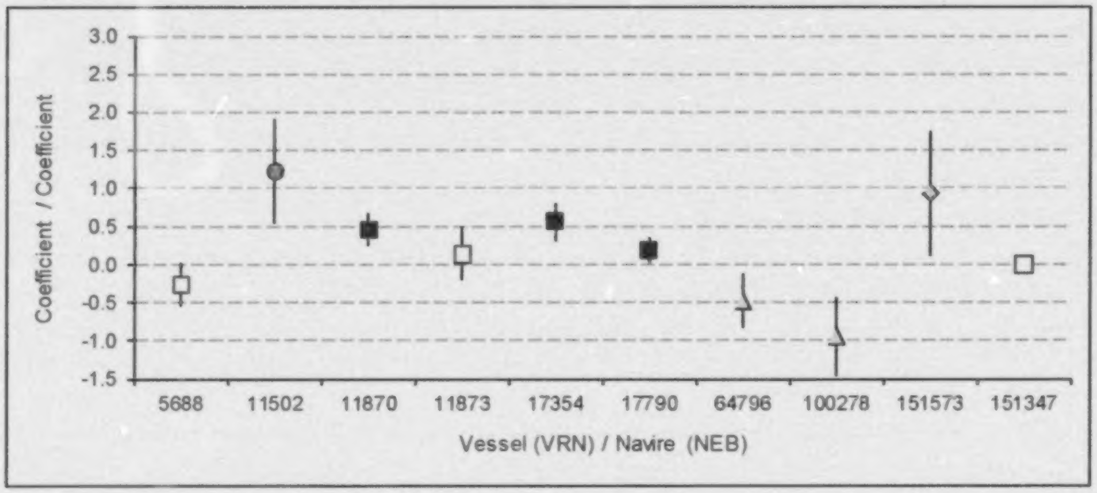


Figure 19: Fishing efficiency coefficients and their confidence intervals for the vessels used to conduct the August sentinel trawl surveys in terms of catch weight. Filled symbols denote vessels that differ from the reference vessel (151347). Vessels denoted by the same filled symbols have a fishing efficiency that does not differ significantly from each other.

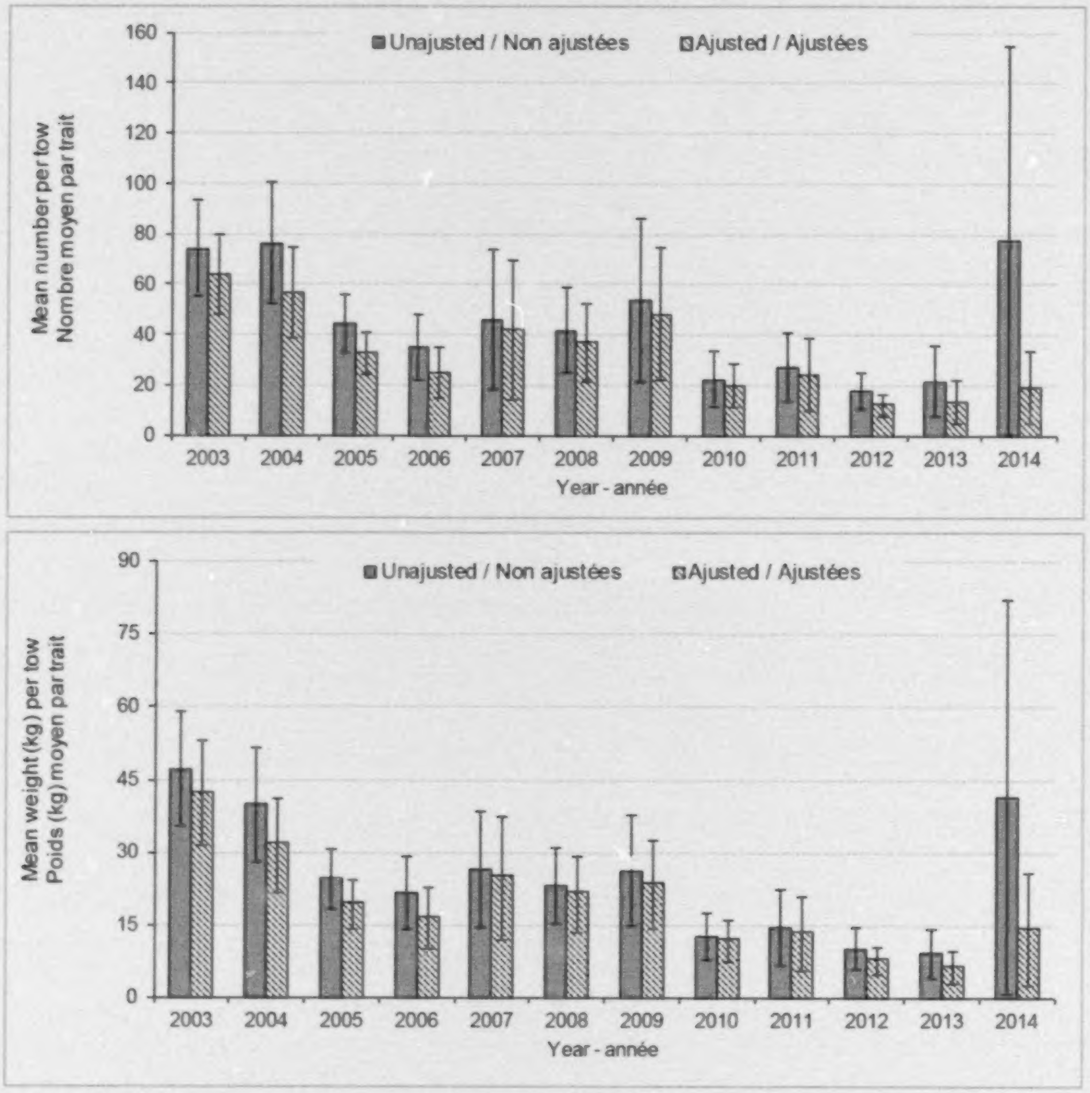
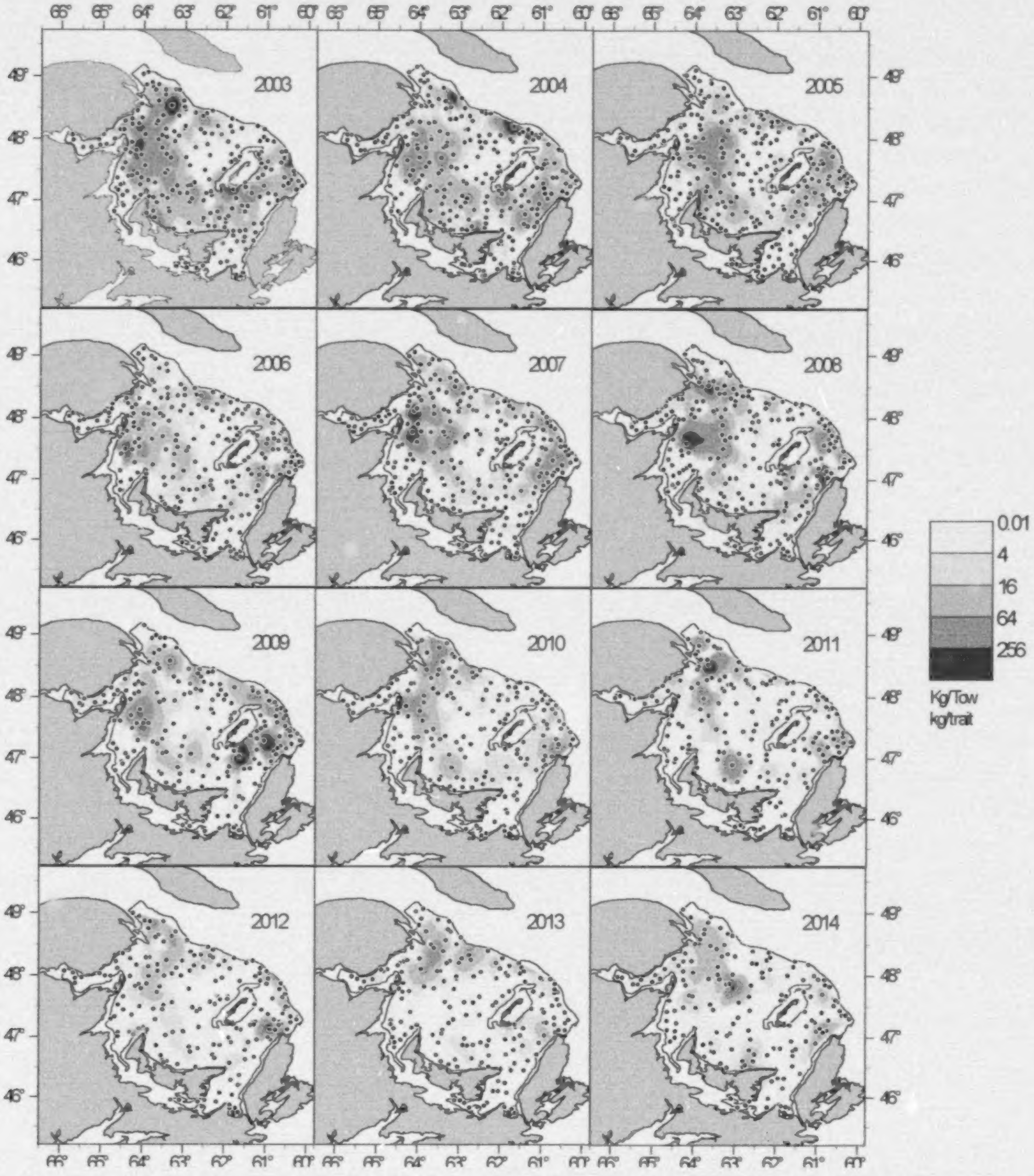


Figure 20: Mean annual numbers (top) and weight (bottom) per tow of Atlantic cod in the sentinel bottom-trawl surveys of the southern Gulf of St. Lawrence, 2003 to 2014. Adjusted values for vessel efficiency are represented by diagonally hatched bars, and unadjusted values are represented by grey bars. Vertical lines denote approximate 95% confidence limits (± 2 standard errors).


66°
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64°
63°
62°
61°
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49°
48°
47°
46°
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
0.01
4
16
64
256
Kg/Tow
kg/trait

Figure 21: Annual spatial distribution of cod catches in the southern Gulf of St. Lawrence from August sentinel bottom-trawl surveys, 2003 to 2014. Catches have been adjusted for vessel differences. The dots indicate the location of fishing sets.

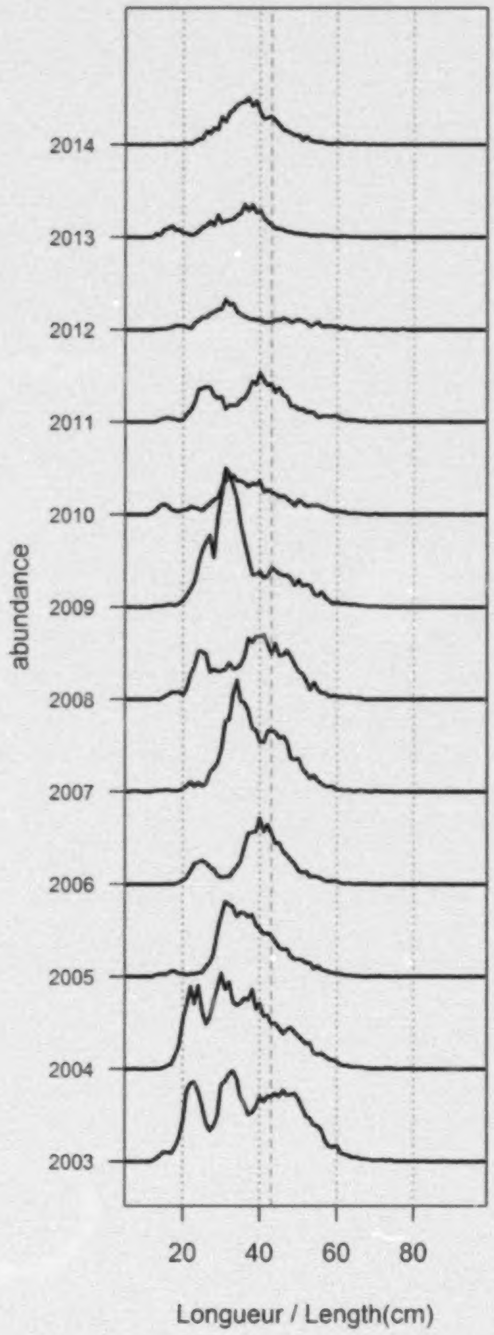


Figure 22: Stratified abundance (mean number per tow) at length for Atlantic cod in in the southern Gulf of St. Lawrence from the August sentinel bottom-trawl surveys, 2003 to 2014. Strata 401 to 439 are those used for the cod abundance index.

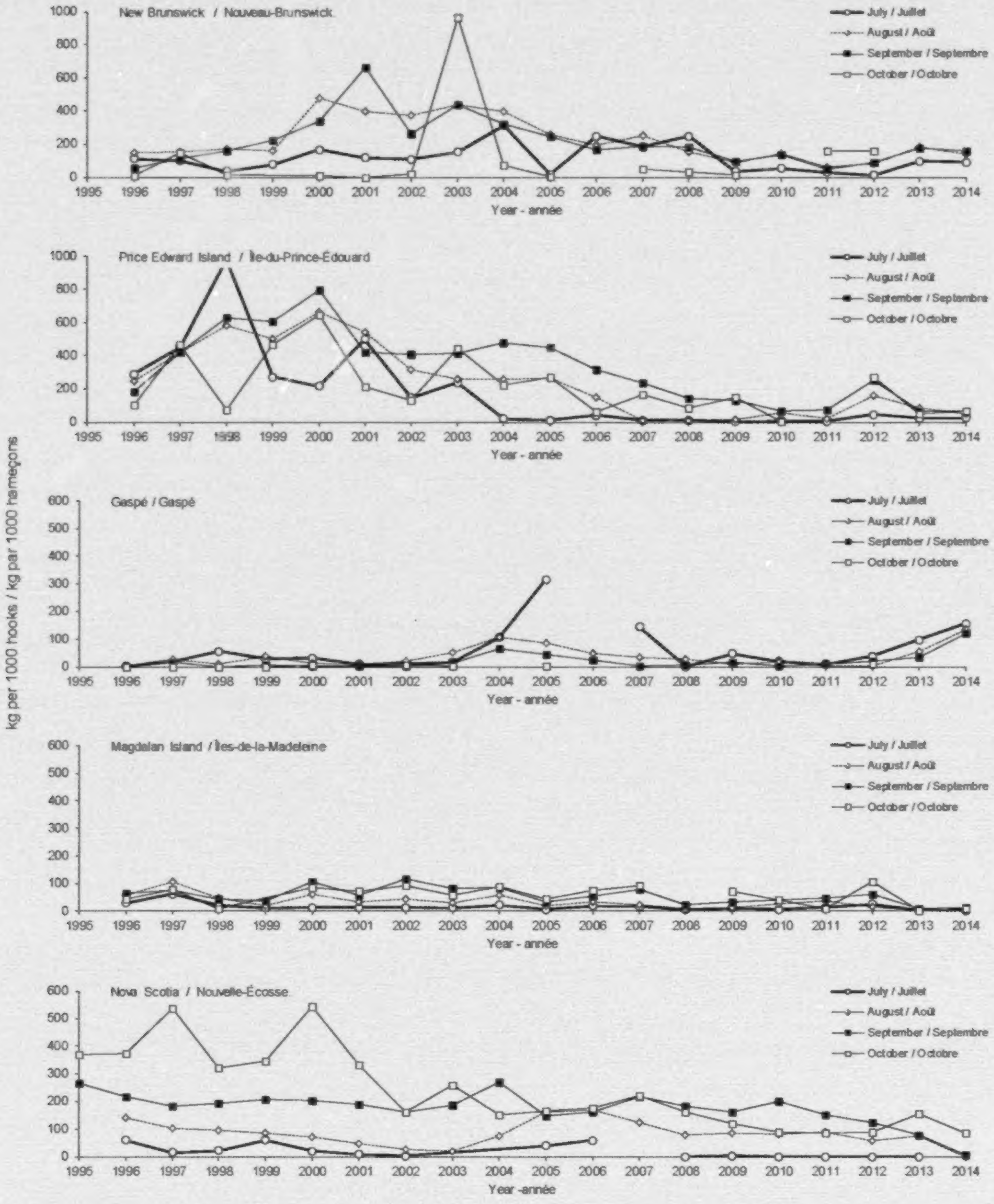


Figure 23: Monthly (July to October) non-standardized catch rates (kg per 1,000 hooks) of Atlantic cod by sites that have been consistently fished in the southern Gulf of St. Lawrence from the sentinel longline surveys, 1995 to 2014.

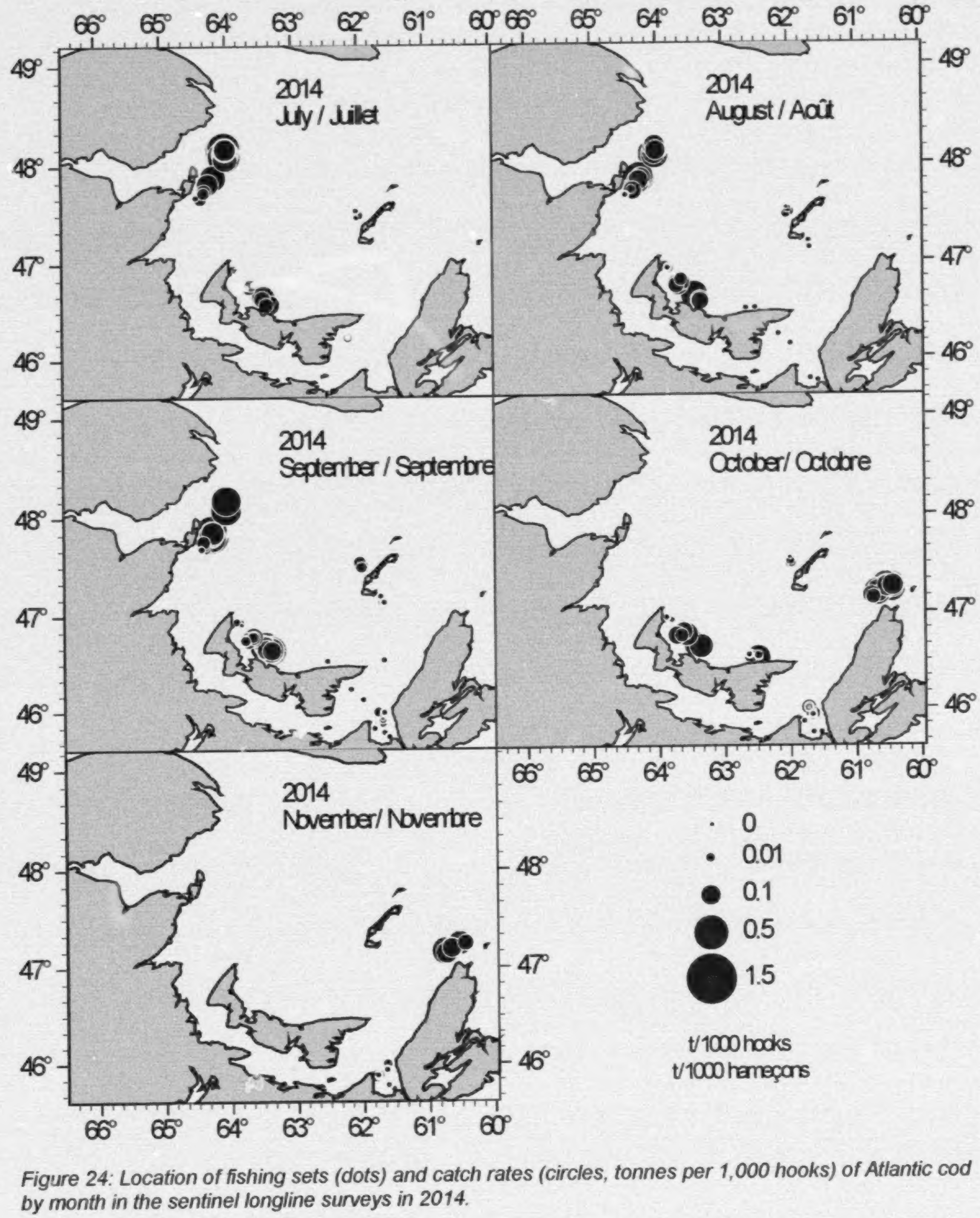

2014
July / Juillet
2014
August / Août
2014
September / Septembre
2014
October/ Octobre
2014
November/ Novembre
66°
65°
64°
63°
62°
61°
60°
49°
48°
47°
46°
0
0.01
0.1
0.5
1.5
t/1000 hooks
t/1000 hameçons

Figure 24: Location of fishing sets (dots) and catch rates (circles, tonnes per 1,000 hooks) of Atlantic cod by month in the sentinel longline surveys in 2014.

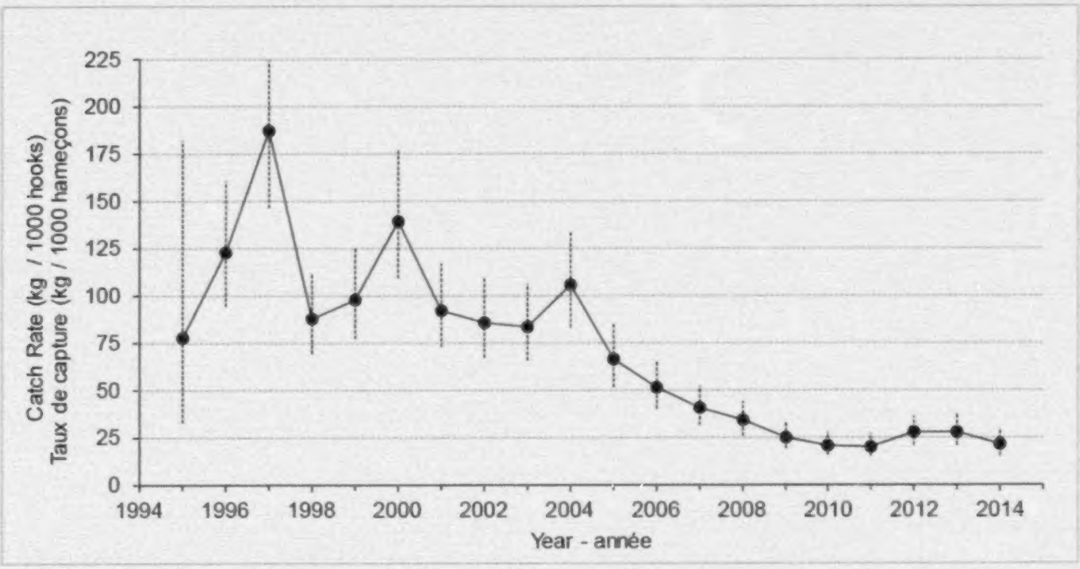


Figure 25: Standardized catch rates (kg per 1,000 hooks) of Atlantic cod in the longline sentinel surveys in the southern Gulf of St. Lawrence, 1995 to 2014. Error bars indicate approximate 95% confidence intervals.

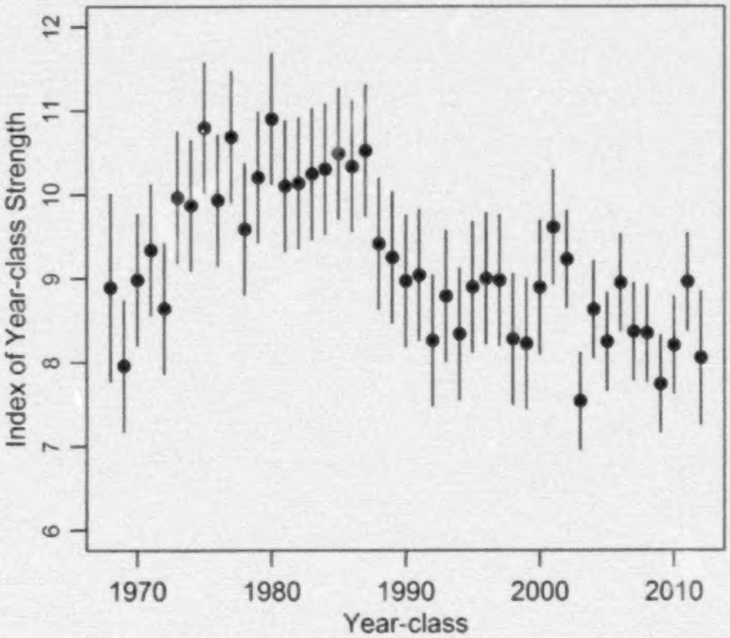


Figure 26: Index of year-class strength based on a multiplicative analysis of $\log_e$ catch rates at ages 2 and 3 years in the RV and mobile sentinel surveys. The index is the predicted $\log_e$ catch rate at age 2 in the RV survey in units of $\log_e$ trawlable abundance (1,000s). Vertical lines are ± 2 SE.

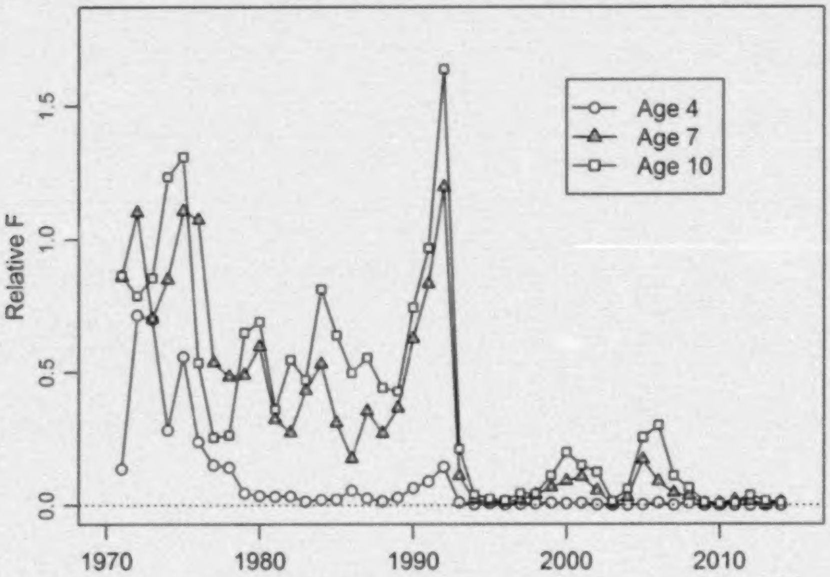


Figure 27: Relative fishing mortality of southern Gulf cod aged 4, 7, and 10 years old, 1971 to 2014. Relative F is fishery catch at age divided by RV survey population indices at age (at the scale of trawlable abundance).

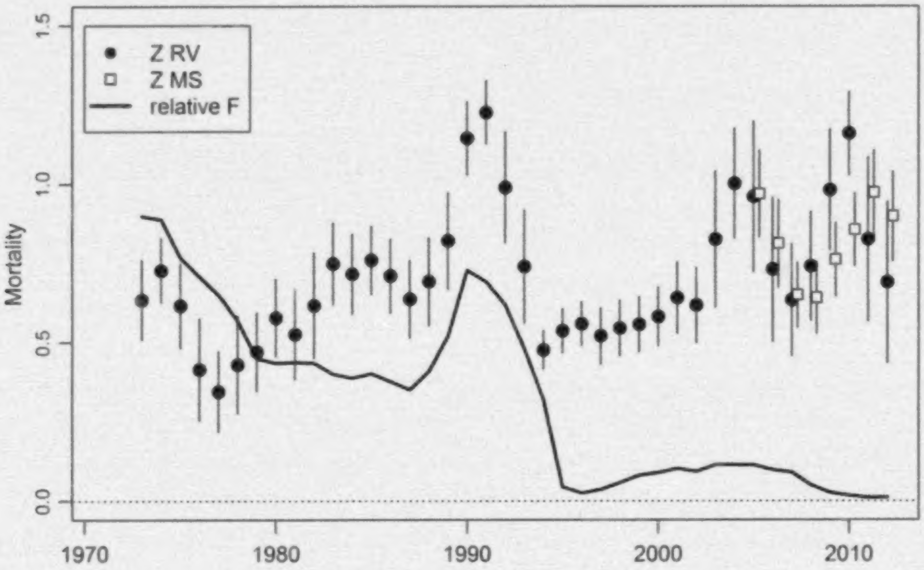


Figure 28: Estimates of the instantaneous rate of total mortality (Z) of Atlantic cod from the southern Gulf of St. Lawrence derived from survey data. Estimates are from an analysis of covariance of the catch rates at age in the September RV survey (closed circles) and August mobile sentinel survey (MS, open squares) Estimates are for moving 5-yr blocks, plotted at the center of each block. Vertical lines are 95% confidence intervals. Lines are relative fishing mortality for ages 7-11 years, averaged over the same 5-yr blocks.

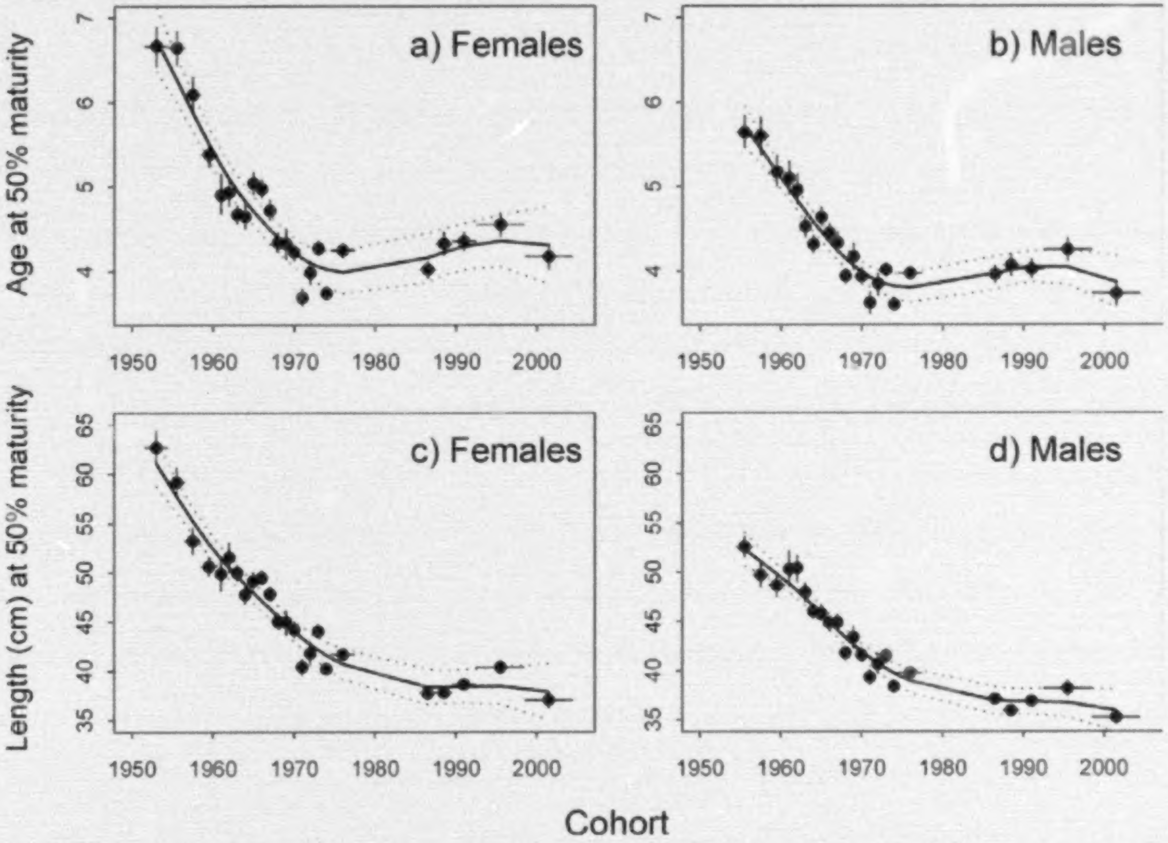


Figure 29: Age (upper row) and length (lower row) at 50% maturity for female (left column) and male (right column) Atlantic cod in the southern Gulf of St. Lawrence (from Swain 2011). Vertical lines are 95% confidence intervals. Horizontal lines indicate the range of cohorts grouped together for the estimate. Time trends are summarized by a smoothing spline (heavy line) ± 2 SE (dotted lines). Lengths have been adjusted to September values.

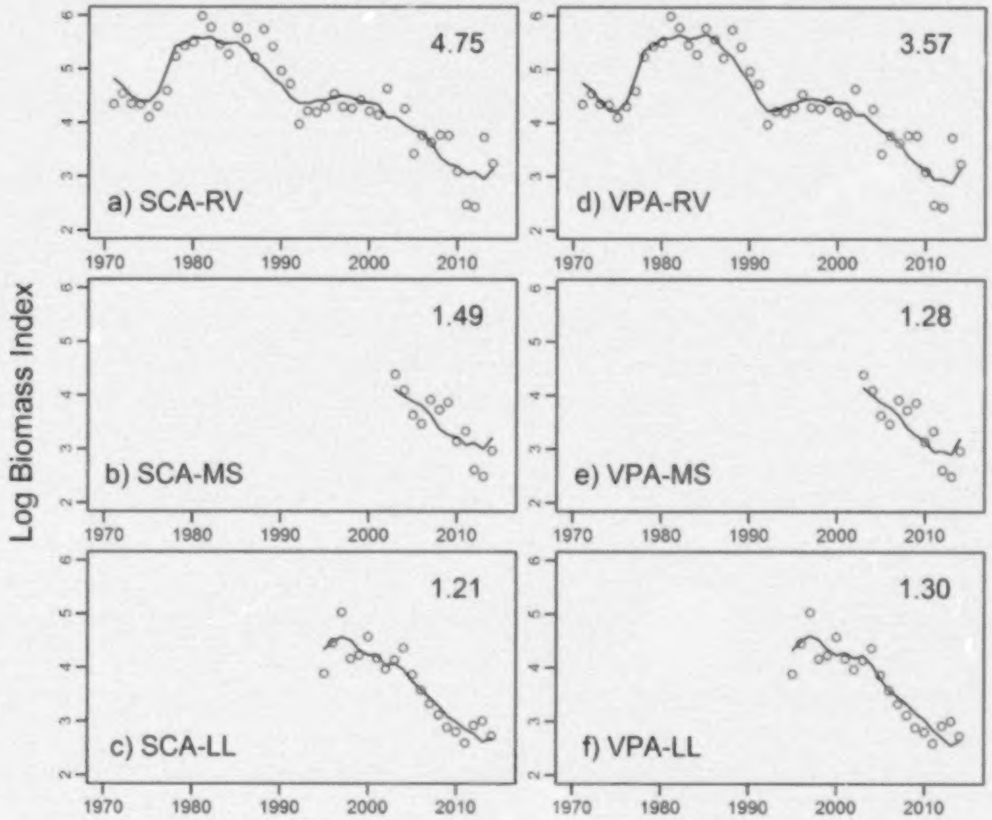


Figure 30: Observed age-aggregated log biomass indices (circles) from the RV survey (RS), mobile sentinel survey (MS, and the sentinel longline program (LL) and the biomass indices predicted (lines) by the SCA (left column) and VPA models (right column). Numbers in the top right corner of each panel are the sum of squared residuals between the observed and predicted log biomass indices.

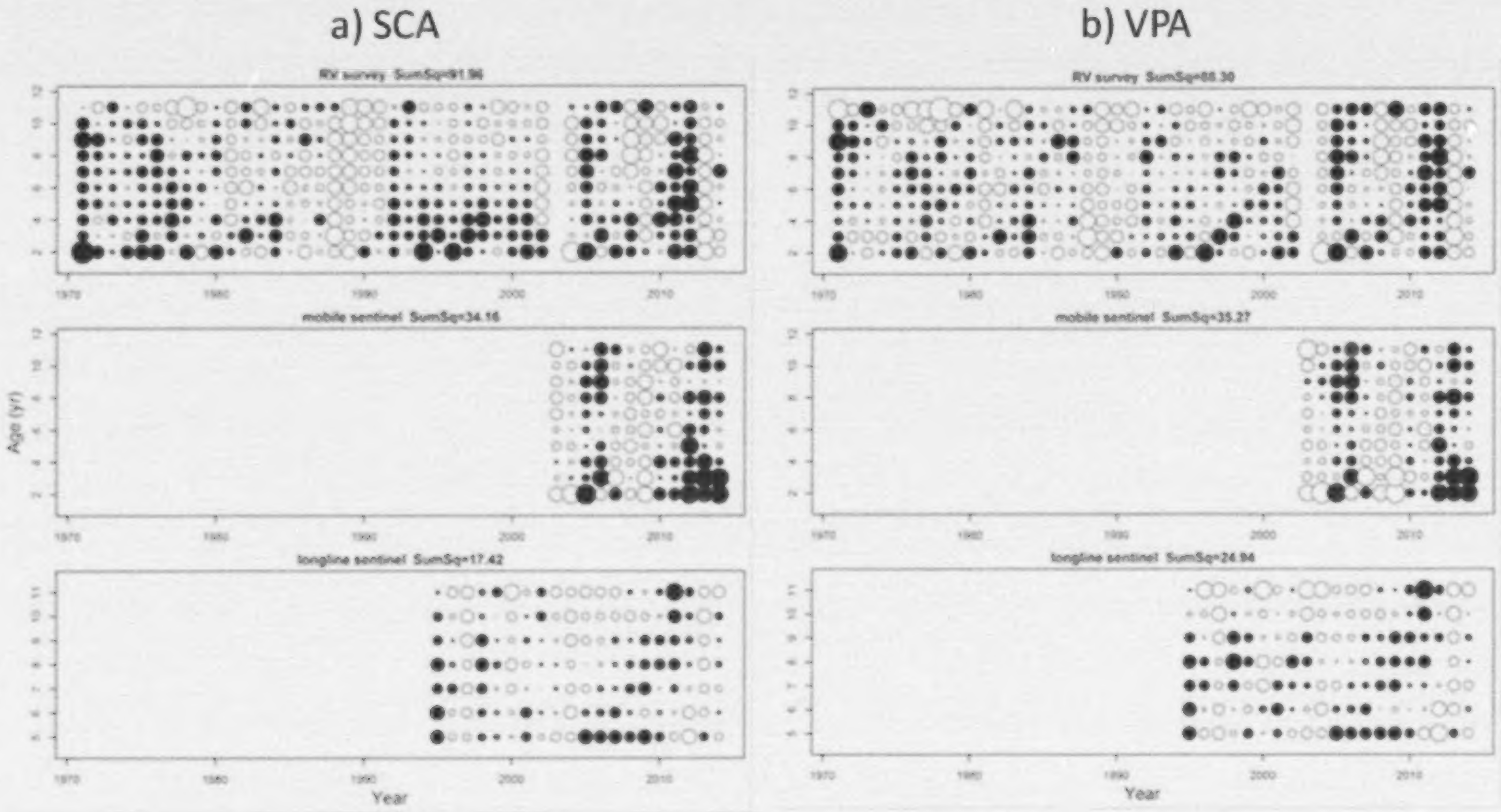


Figure 31: Residuals between observed and predicted abundance at age (log(observed/predicted)) for the SCA (left column, a) and VPA (right column, b) models. Residuals are proportional to circle radius. Black circles denote negative residuals (i.e., observed < predicted).

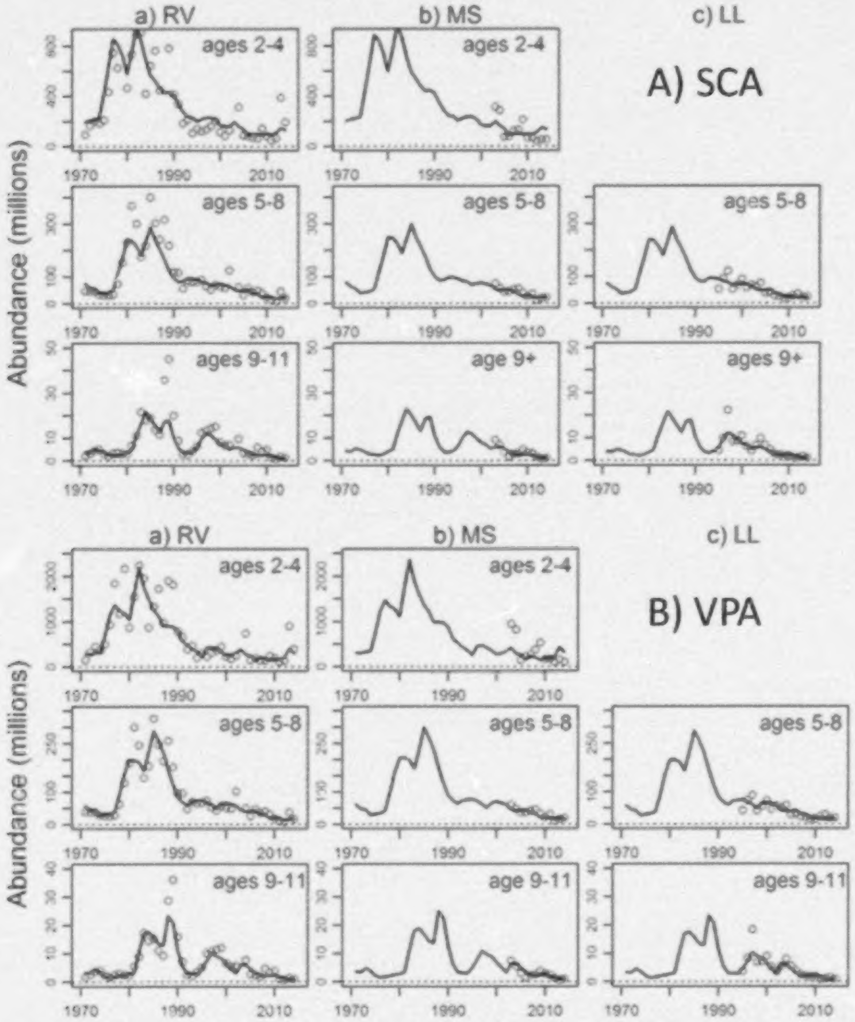


Figure 32: Comparison of catchability-corrected abundance indices (circles) and model predictions (lines) of abundance indices of Atlantic cod adjusted to the time of year when the index data were collected. Panels in A) are predictions of the SCA model. Panels in B) area predictions of the VPA model. In each panel, a) are the RV survey indices, b) the mobile sentinel indices, and c) the sentinel longline indices.

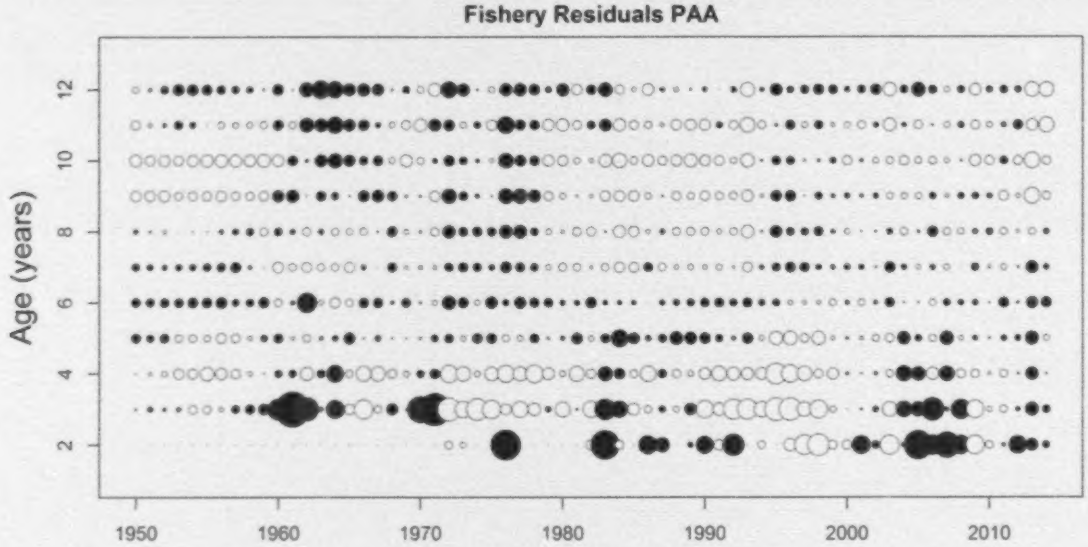


Figure 33: Residuals between the observed proportions at age in the fishery catch and the proportions predicted by the SCA model. Residuals are proportional to circle radii. Black circles denote negative residuals (i.e., observed < predicted).

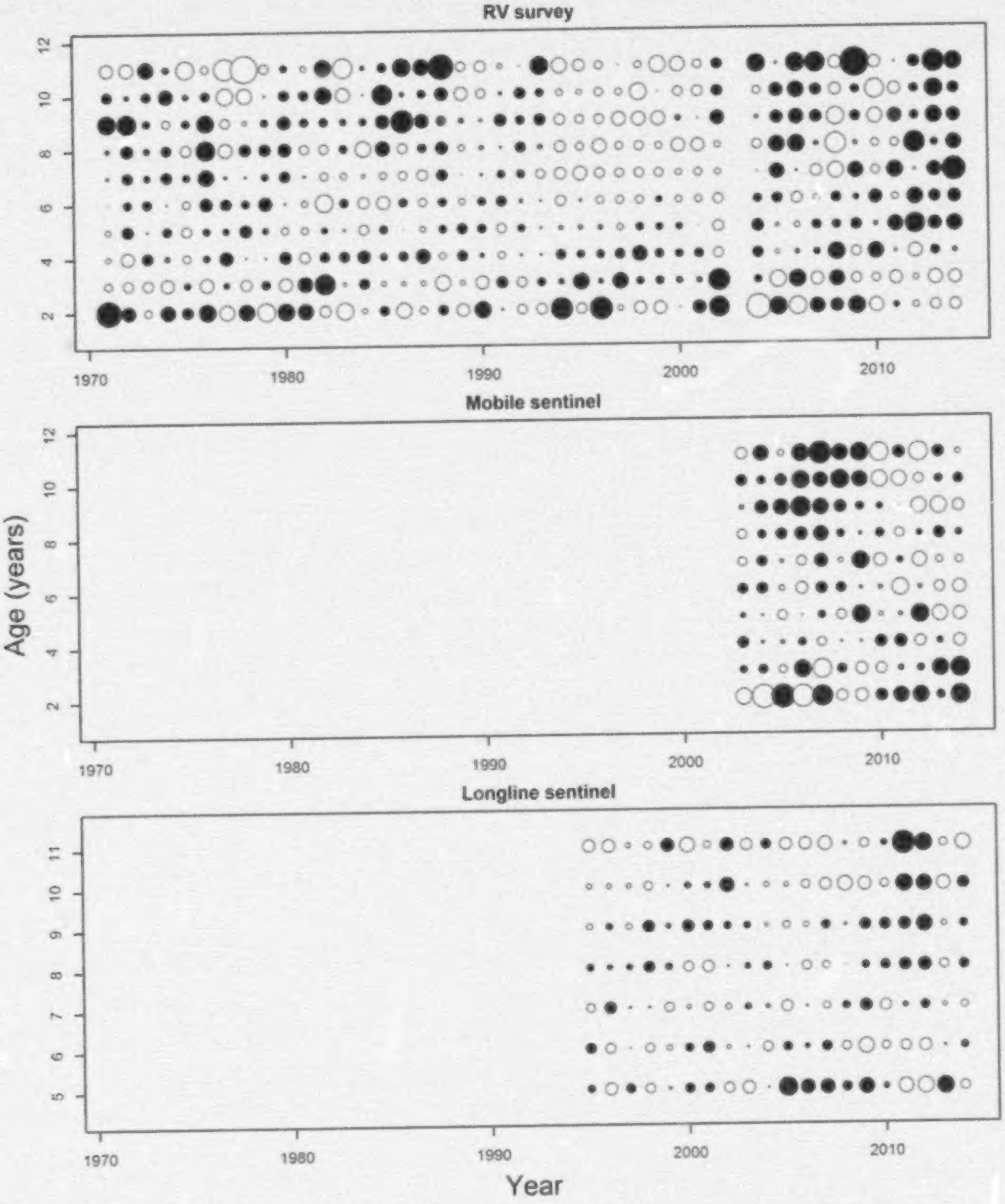
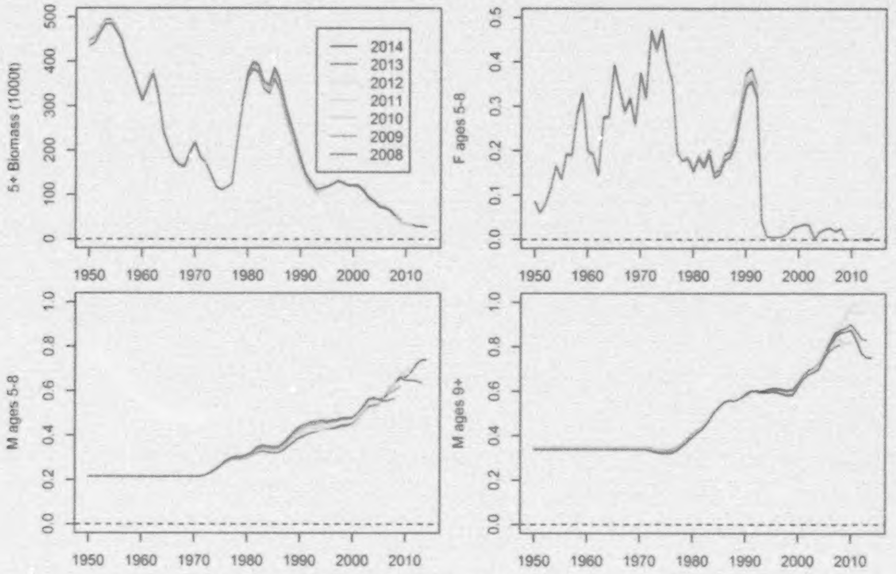


Figure 34: Residuals between the observed proportions at age in the abundance indices and the proportions predicted by the SCA model. Residuals are proportional to circle radii. Black circles denote negative residuals (i.e., observed < predicted).

a) SCA



b) VPA

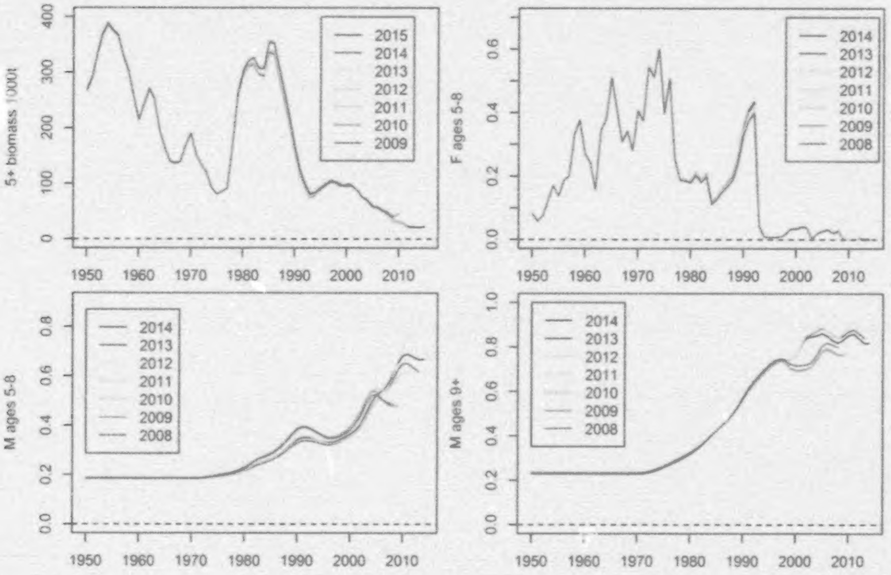


Figure 35: Retrospective analysis of estimates of southern Gulf of St. Lawrence Atlantic cod 5+ biomass, F at ages 5-8 years, and M at ages 5-8 and 9+ years from the SCA model (panel a) and the VPA model (panel b), 1950 to 2014.

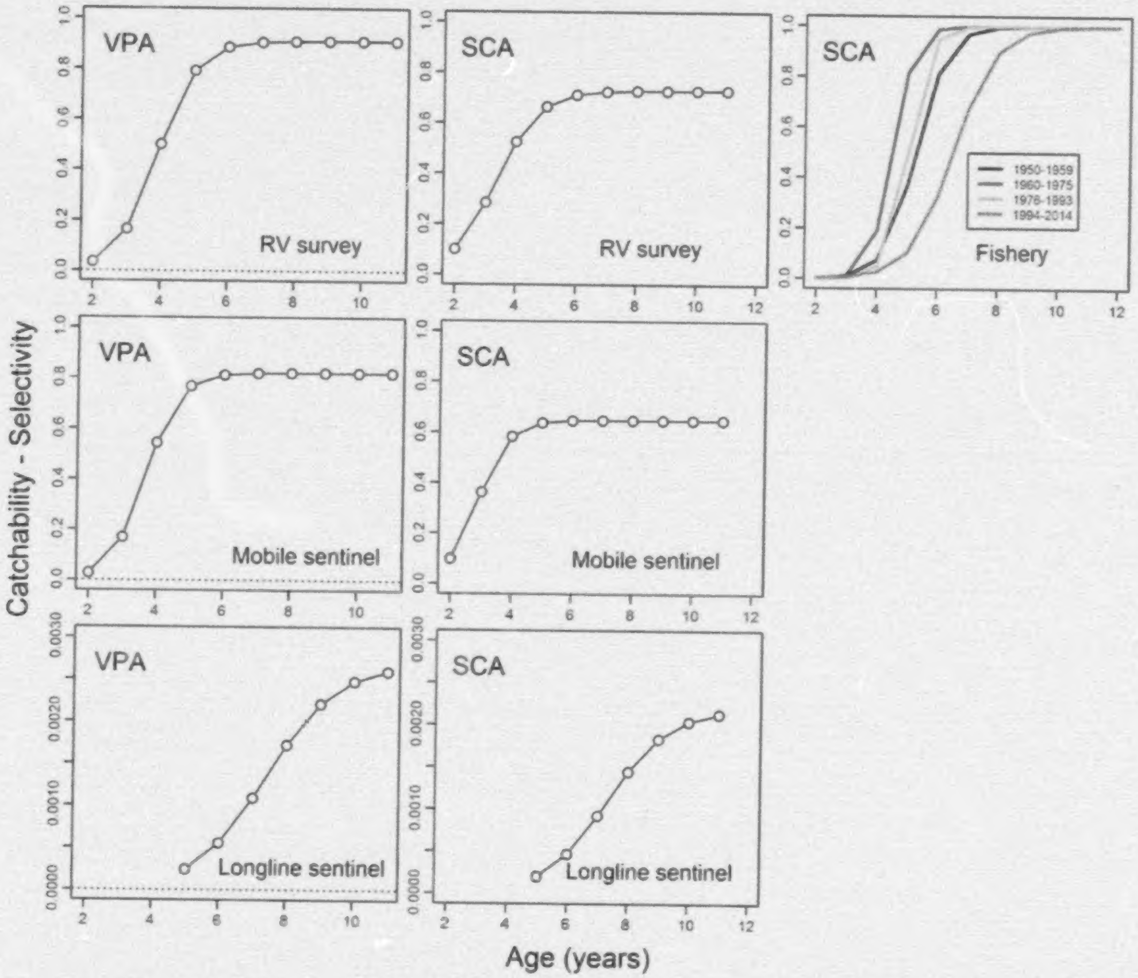


Figure 36: VPA (left column) and SCA (middle column) estimates of catchabilities at age to the RV survey (top row), the mobile sentinel survey (middle row), and the longline sentinel program (bottom row). The selectivity at age to the fishery from the SCA model is shown in the upper right panel.

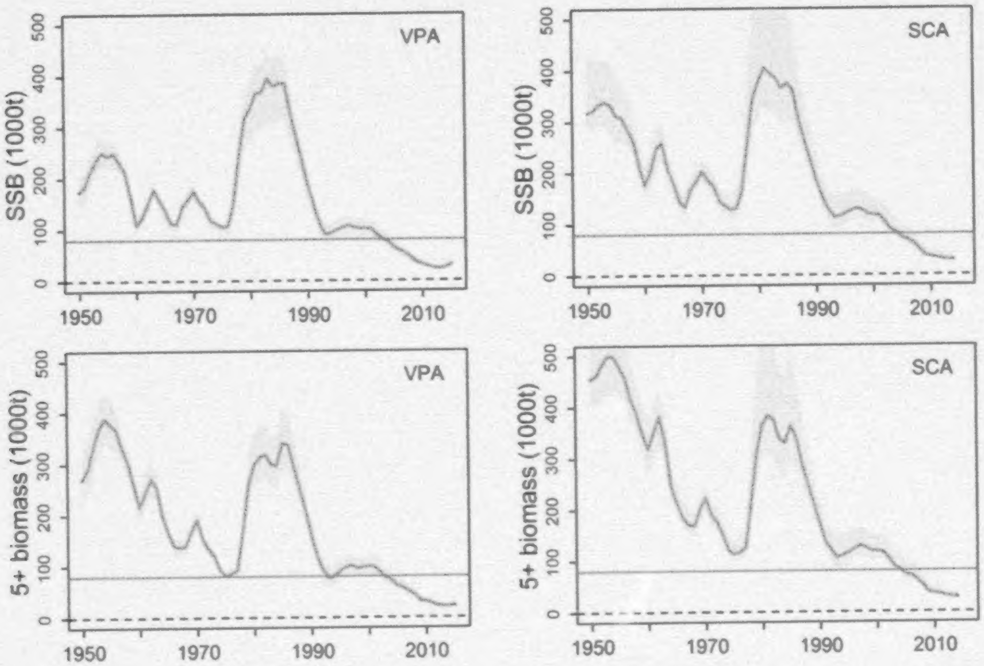


Figure 37: VPA (left column) and SCA (right column) estimates of spawning stock biomass (SSB by 1000 t; top row) and 5+ biomass (by 1,000 t; bottom row) for southern Gulf of St. Lawrence Atlantic cod. Lines show the maximum-likelihood estimates and shading their approximate 95% confidence intervals based on MCMC sampling. The horizontal red line is the limit reference point value of 80,000 t of SSB.

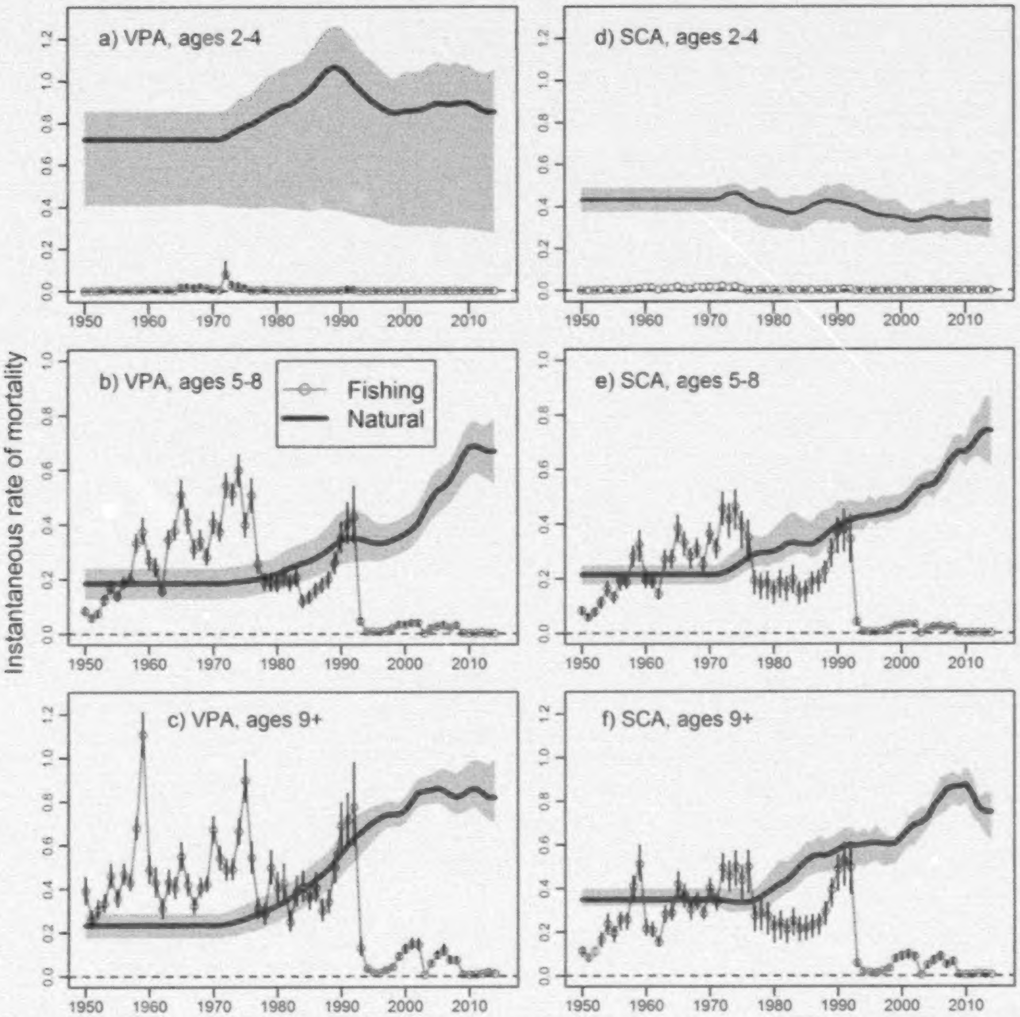


Figure 38: VPA (left column) and SCA (right column) estimates of the instantaneous rates of fishing (F; circle symbols) and natural (M; blue lines) mortality of southern Gulf of St. Lawrence Atlantic cod for ages 2 to 4 (upper row), ages 5 to 8 (middle row), and ages 9+ (bottom row), 1950 to 2014. Circles and blue lines show the maximum-likelihood estimates, and vertical lines and blue shading their approximate 95% confidence intervals based on MCMC sampling. F values are abundance-weighted averages of the values at each age within age groups.

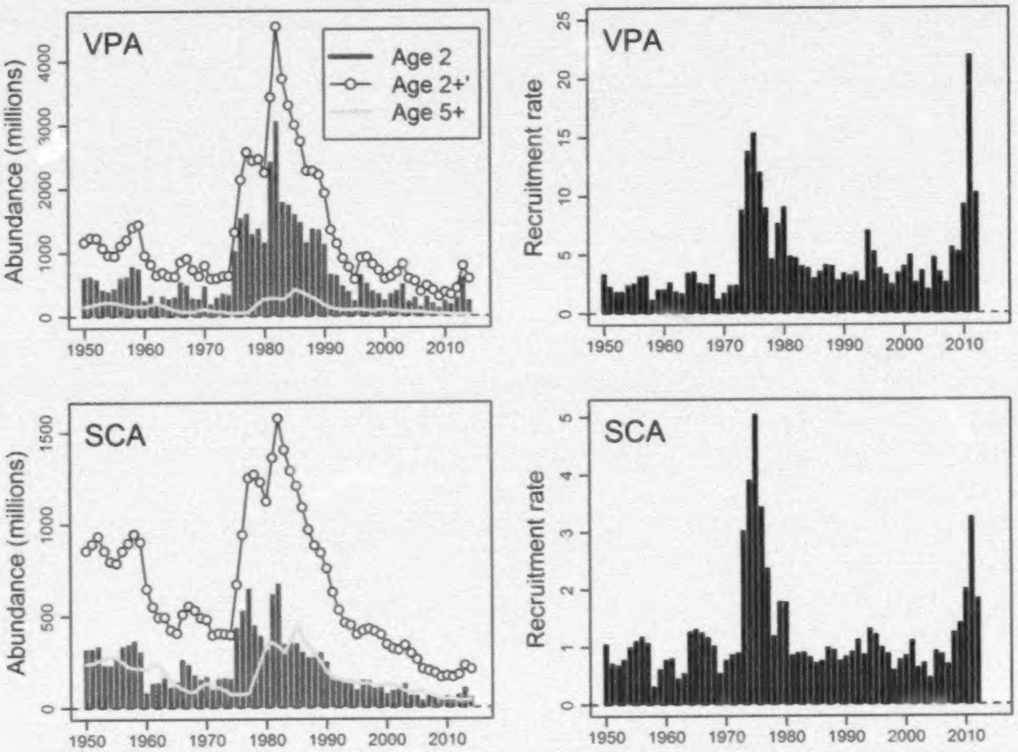


Figure 39: VPA (top row) and SCA (bottom row) estimates of abundance at age 2, 2+ and 5+ (millions, left column) for 1950 to 2014 and recruitment rates (thousands of age-2 recruits per ton of spawning stock biomass; right column) for the 1950 to 2012 year classes.

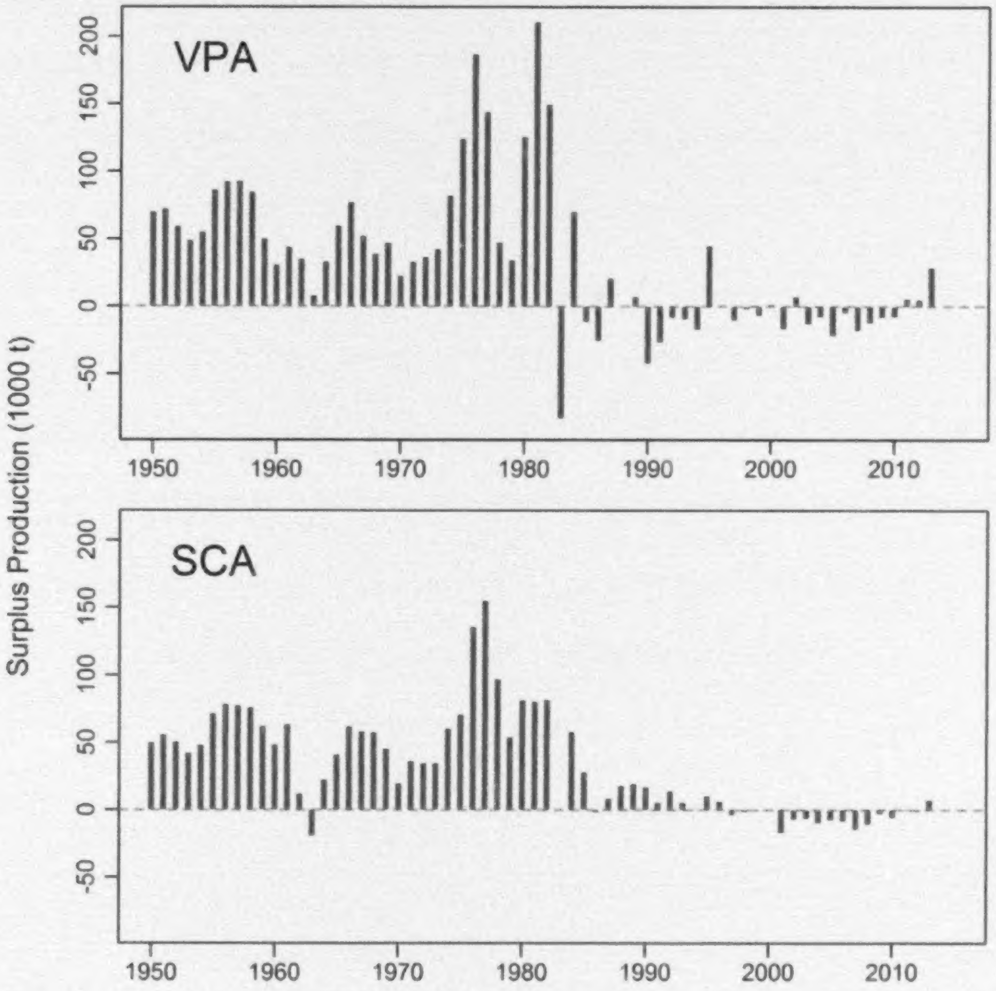


Figure 40: Surplus production (by 1,000 t) of southern Gulf of St. Lawrence Atlantic cod estimated by VPA (upper panel) and SCA (lower panel) models, 1950 to 2013.

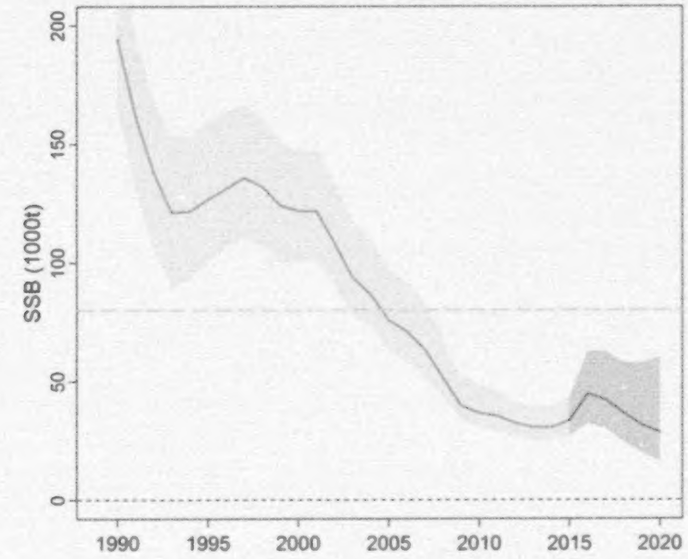


Figure 41: Estimated (green line and shading) and projected (red line and shading) SSB (1,000 t) of Atlantic cod from the southern Gulf of St. Lawrence based on the SCA model. The projections assume current productivity and no fishery catches. Lines show the median and shading the 95% confidence band based on 5000 saved MCMC iterations. The horizontal gold dashed line is the LRP value of 80,000 tonnes of SSB.

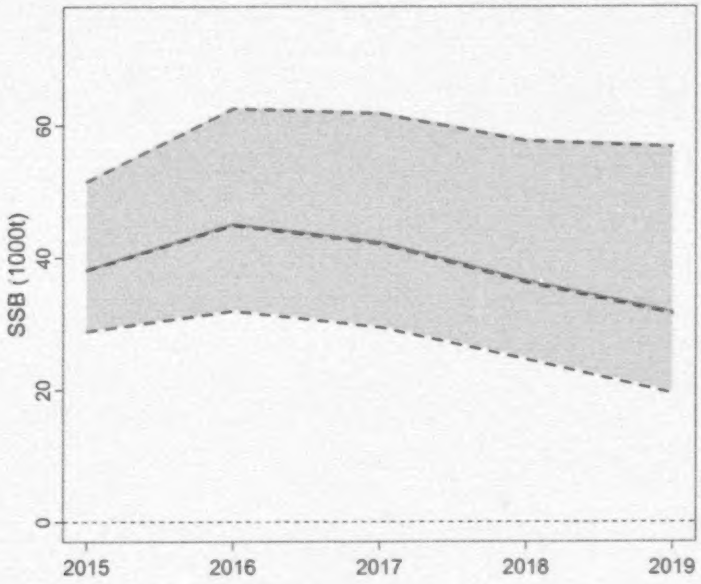


Figure 42: Projected SSB of southern Gulf of St. Lawrence Atlantic cod from the SCA model with no fishery catch (solid red line and shading, median projection and 95% confidence intervals) or a catch of 300 t (blue dashed lines, median projection and 95% confidence intervals), 2015 to 2019.

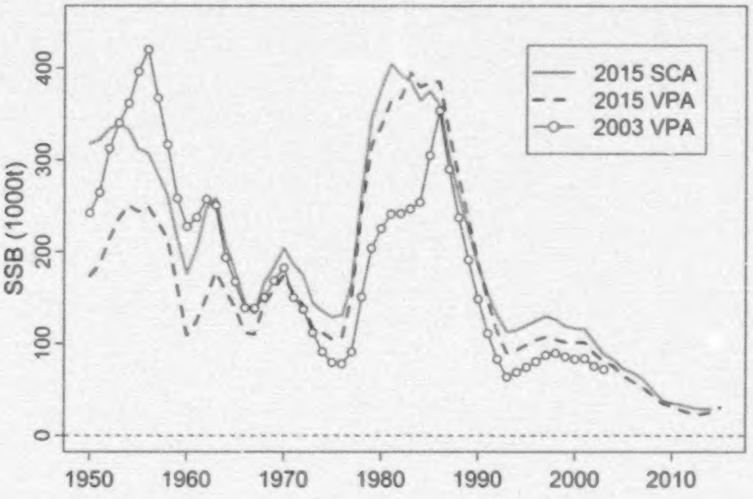


Figure 43: Estimated SSB (by 1,000 t) of southern Gulf of St. Lawrence Atlantic cod based on the models presented here (2015 SCA, 2015 VPA) and in Chouinard et al. (2003b) (2003 VPA).

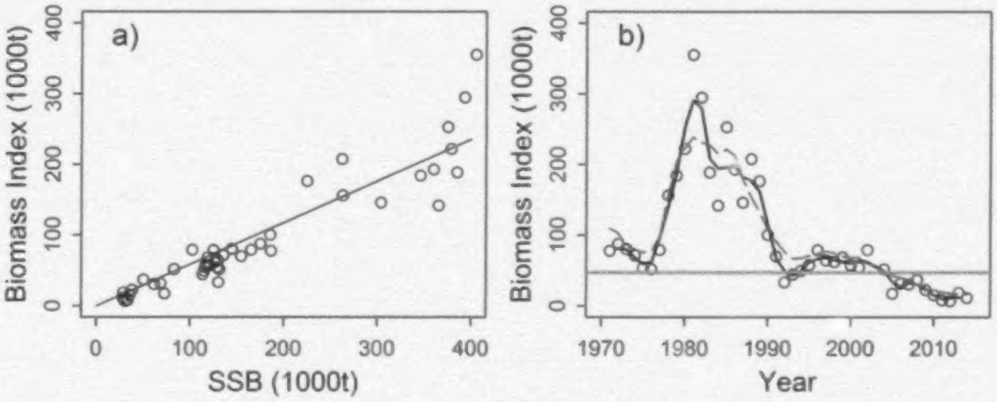


Figure 44: Re-scaling the LRP to the scale of the RV biomass index for Atlantic cod 42 cm and larger from the southern Gulf of St. Lawrence. Panel a (left) shows the biomass index at the scale of trawlable biomass versus estimated spawning stock biomass (SSB) from the model. Circles are the observed index and the line shows the predicted index. Panel b (right) shows the time trend in the observed biomass index (circles), the index predicted from SSB (dashed green line), and the 3-year moving average of the observed index (solid black line). The horizontal red line in panel b) is the value of the limit reference point (LRP) at the scale of the biomass index, expressed as trawlable biomass.

APPENDICES

APPENDIX A: LANDINGS BY MONTH AND GEAR, 2009-2014

Table A1a: Landings (tonnes) by month and gear for southern Gulf of St. Lawrence cod in 2009.

Month	Trawl	Seine	Gillnet	Longline	Handline	Misc.	Total
Jan	0.05	-	-	-	-	-	0.05
Feb	-	-	-	-	-	-	-
Mar	-	-	-	-	-	-	-
Apr	-	-	0.20	-	-	0.05	0.25
May	1.21	9.25	0.04	7.00	-	-	17.49
Jun	3.80	11.50	0.03	9.46	-	-	24.79
Jul	2.10	0.46	3.00	6.98	1.91	0.03	14.48
Aug	1.61	1.11	1.60	11.75	4.06	-	20.14
Sep	2.16	0.27	0.10	10.84	0.94	-	14.31
Oct	22.17	3.77	0.01	-	-	0.01	25.96
Nov	-	0.09	-	-	-	-	0.09
Dec	-	-	-	-	-	-	-
Total	33.09	26.45	4.97	46.04	6.91	0.09	117.55

Table A1b: Landings (tonnes) of cod from NAFO Division 4T in 2009 in the Sentinel Survey.

Month	Longline	Trawl-Lined	Total
Jul	1.42	-	1.42
Aug	3.48	6.02	9.49
Sep	15.36	-	15.36
Oct	5.35	-	5.35
Nov	0.01	-	0.01
Dec	-	-	-
Total	25.61	6.02	31.63

Table A2a: Landings (tonnes) by month and gear for southern Gulf of St. Lawrence cod in 2010.

Month	Trawl	Seine	Gillnet	Longline	Handline	Misc.	Total
Jan	-	-	-	-	-	-	-
Feb	0.01	-	-	-	-	-	0.01
Mar	-	-	-	-	-	-	-
Apr	-	-	0.21	7.62	-	-	7.83
May	-	1.89	0.04	0.39	-	-	2.32
Jun	1.03	6.61	0.68	6.48	-	-	14.79
Jul	5.13	2.48	1.78	13.35	2.20	-	24.93
Aug	0.13	1.29	1.52	7.01	5.55	-	15.50
Sep	-	0.32	0.20	7.25	0.80	-	8.58
Oct	2.03	1.00	-	-	-	-	3.02
Nov	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-
Total	8.33	13.58	4.45	42.09	8.55	-	76.99

Table A2b: Landings (tonnes) of cod from NAFO Division 4T in 2010 in the Sentinel Survey.

Month	Longline	Trawl-Lined	Total
Jul	1.02	-	1.02
Aug	6.86	3.08	9.94
Sep	11.53	-	11.53
Oct	3.27	-	3.27
Nov	0.23	-	0.23
Dec	-	-	-
Total	22.91	3.08	25.99

Table A3a: Landings (tonnes) by month and gear for southern Gulf of St. Lawrence cod in 2011.

Month	Trawl	Seine	Gillnet	Longline	Handline	Misc.	Total
Jan	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	-
Mar	-	-	-	0.32	-	-	0.32
Apr	-	-	0.04	12.91	-	-	12.95
May	-	1.97	0.09	3.39	-	-	5.45
Jun	0.45	4.39	0.14	10.30	-	-	15.27
Jul	0.38	3.05	2.00	9.76	3.69	-	18.87
Aug	-	1.48	1.46	13.93	7.43	0.04	24.33
Sep	0.12	1.03	0.82	11.73	1.81	-	15.50
Oct	-	0.18	0.01	0.16	0.01	-	0.36
Nov	0.55	1.54	-	0.46	-	-	2.56
Dec	-	-	-	-	-	-	-
Total	1.50	13.63	4.55	62.95	12.93	0.04	95.60

Table A3b: Landings (tonnes) of cod from NAFO Division 4T in 2011 in the Sentinel Survey.

Month	Longline	Trawl-Lined	Total
Jul	0.45	-	0.45
Aug	3.93	2.73	6.65
Sep	8.70	-	8.70
Oct	2.98	-	2.98
Nov	-	-	-
Dec	-	-	-
Total	16.05	2.73	18.78

Table A4a: Landings (tonnes) by month and gear for southern Gulf of St. Lawrence cod in 2012.

Month	Trawl	Seine	Gillnet	Longline	Handline	Misc.	Total
Jan	-	-	-	0.07	-	-	0.07
Feb	-	-	-	0.03	-	-	0.03
Mar	-	-	-	1.74	-	-	1.74
Apr	-	0.38	0.07	45.29	1.02	-	46.77
May	0.02	4.45	1.94	0.07	-	-	6.47
Jun	1.38	2.42	0.57	7.63	-	-	12.00
Jul	2.64	4.36	2.16	8.16	0.03	-	17.34
Aug	0.18	0.85	0.78	24.48	4.40	-	30.70
Sep	0.21	0.11	0.64	14.52	14.35	-	29.82
Oct	-	0.04	0.41	0.06	-	-	0.51
Nov	-	-	-	0.08	-	-	0.08
Dec	-	-	-	-	-	-	-
Total	4.42	12.61	6.56	102.12	19.80		145.51

Table A4b: Landings (tonnes) of cod from NAFO Division 4T in 2012 in the Sentinel Survey.

Month	Longline	Trawl-Lined	Total
Jul	1.39	-	1.39
Aug	4.43	2.47	6.90
Sep	13.23	-	13.23
Oct	4.36	-	4.36
Nov	0.63	-	0.63
Dec	-	-	-
Total	24.03	2.47	26.50

Table A5a: Landings (tonnes) by month and gear for southern Gulf of St. Lawrence cod in 2013.

Month	Trawl	Seine	Gillnet	Longline	Handline	Misc.	Total
Jan	-	-	-	-	-	-	-
Feb	-	-	-	0.04	-	-	0.04
Mar	-	-	-	0.22	-	-	0.22
Apr	-	1.69	0.89	1.78	-	-	4.36
May	-	2.58	0.95	3.16	-	-	6.69
Jun	0.79	0.97	0.35	16.61	-	-	18.72
Jul	0.12	1.59	2.76	13.58	-	-	18.05
Aug	0.06	0.18	2.51	9.74	2.09	0.01	14.59
Sep	-	-	0.17	10.20	-	-	10.38
Oct	0.22	-	-	16.06	-	-	16.28
Nov	-	0.07	-	0.26	-	-	0.33
Dec	0.74	-	-	0.02	-	-	0.76
Total	1.92	7.09	7.63	71.67	2.09	0.01	90.41

Table A5b: Landings (tonnes) of cod from NAFO Division 4T in 2013 in the Sentinel Survey.

Month	Longline	Trawl-Lined	Total
Jul	2.45	-	2.45
Aug	5.29	1.62	6.90
Sep	6.67	-	6.67
Oct	4.77	-	4.77
Nov	0.08	-	0.08
Dec	-	-	-
Total	19.27	1.62	20.89

Table A6a: Landings (tonnes) by month and gear for southern Gulf of St. Lawrence cod in 2014 (preliminary).

Month	Trawl	Seine	Gillnet	Longline	Handline	Misc.	Total
Jan	3.17	-	-	0.23	-	-	3.41
Feb	0.01	-	-	0.19	-	-	0.20
Mar	-	-	-	-	-	-	-
Apr	-	-	1.18	-	-	-	1.18
May	-	6.61	0.52	3.12	-	-	10.24
Jun	0.36	10.93	0.91	4.74	-	-	16.94
Jul	3.07	1.16	0.41	12.76	-	-	17.39
Aug	0.29	-	0.04	16.32	-	-	16.65
Sep	0.27	0.14	0.12	14.06	-	-	14.59
Oct	0.03	-	0.04	14.44	-	-	14.50
Nov	-	-	-	0.47	-	-	0.47
Dec	-	-	-	-	-	-	-
Total	7.20	18.84	3.21	66.32	-	-	95.56

Table A6b: Landings (tonnes) of cod from NAFO Division 4T in 2014 in the Sentinel Survey.

Month	Longline	Trawl-Lined	Total
Jul	2.61	-	2.61
Aug	3.68	4.13	7.81
Sep	4.40	-	4.40
Oct	3.28	-	3.28
Nov	0.80	-	0.80
Dec	-	-	-
Total	14.77	4.13	18.91

APPENDIX B: AGE-LENGTH KEYS USED TO CALCULATE THE CATCH-AT-AGE IN THE 2009 TO 2014 FISHERIES

Table B1a: Age-length keys that were used in the calculation of the 2009 catch-at-age for southern Gulf of St. Lawrence cod.

Key	Fishery	Samples	Total (N)	Landings (t)
1	OTB/SNU - Bycatch: Apr. - Sept. (No Liners)	OTB/SNU - Bycatch: Apr. - Sept. Lengths (No Liners)	1667	33.458
		OTB/SNU - Bycatch: Apr. - Sept. Ages (No Liners)	264	
2	OTB/SNU - Bycatch: Oct. - Dec. (No Liners)	OTB/SNU - Bycatch: Oct. - Dec. Lengths (No Liners)	2119	26.035
		OTB/SNU - Bycatch: Oct. - Dec. Ages (No Liners)	621	
3	GN/LL/LHP - Bycatch: May - Nov.	GN/LL/LHP - Bycatch: May - Nov. Lengths	1153	57.920
		GN/LL/LHP – Bycatch & Sentinel: May - Nov. Ages	981	
4	LL - Sentinel Survey: Jul. – Nov.	LL - Sentinel Survey: Jul. – Nov. Lengths	14609	25.608
		LL - Sentinel Survey: Jul. – Nov. Ages	828	
5	OTB - Sentinel Survey: Aug. (Liners)	OTB - Sentinel Survey: Aug. Lengths (Liners)	6939	6.019
		OTB - Sentinel Survey: Aug. Ages (Liners)	1650	
NA	Un-sampled	NA	NA	0.138
Total				149.178

Gear Type Abbreviations: OTB = Otter Trawl, SNU = Seine, GN = Gillnet, LL = Longline, LHP = Handline

Length/Weight Coefficients (sexes combined) from Mission T992 (Sept. 2009): a = 0.0000104, b = 2.9626

Table B1b: Age-length keys that were used in the calculation of the 2010 catch-at-age for southern Gulf of St. Lawrence cod.

Key	Fishery	Samples	Total (N)	Landings (t)
1	OTB/SNU - Bycatch: May. - Oct. (No Liners)	OTB/SNU - Bycatch: May. - Oct. Lengths (No Liners)	710	21.887
		OTB/SNU - Bycatch: May. - Oct. Ages (No Liners)	326	
2	GN/LL/LHP - Bycatch: Apr. - Nov.	GN/LL/LHP - Bycatch: Apr. - Nov. Lengths	614	55.088
		GN/LL/LHP – Bycatch & Sentinel: Apr. - Nov. Ages	1523	
3	LL - Sentinel Survey: Jul. – Nov.	LL - Sentinel Survey: Jul. – Nov. Lengths	13577	22.910
		LL - Sentinel Survey: Jul. – Nov. Ages	1300	
4	OTB - Sentinel Survey: Aug. (Liners)	OTB - Sentinel Survey: Aug. Lengths (Liners)	3719	3.076
		OTB - Sentinel Survey: Aug. Ages (Liners)	1300	
NA	Un-sampled	NA	NA	0.014
Total				102.975

Gear Type Abbreviations: OTB = Otter Trawl, SNU = Seine, GN = Gillnet, LL = Longline, LHP = Handline

Length/Weight Coefficients (sexes combined) from Mission T074 (Sept. 2010): a = 0.0000070, b = 3.0588

Table B1c: Age-length keys that were used in the calculation of the 2011 catch-at-age for southern Gulf of St. Lawrence cod.

Key	Fishery	Samples	Total (N)	Landings (t)
1	OTB/SNU - Bycatch: May. - Nov. (No Liners)	OTB/SNU - Bycatch: May. - Nov. Lengths (No Liners)	72	15.124
		OTB/SNU - Bycatch: May. - Nov. Ages (No Liners)	62	
2	GN/LL/LHP - Bycatch: Apr. - Oct.	GN/LL/LHP - Bycatch: Apr. - Oct. Lengths	1043	80.115
		GN/LL/LHP – Bycatch: Apr. - Oct. Ages	580	
3	LL - Sentinel Survey: Jul. – Nov.	LL - Sentinel Survey: Jul. – Nov. Lengths	9214	16.048
		LL - Sentinel Survey: Jul. – Nov. Ages	1140	
4	OTB - Sentinel Survey: Aug. (Liners)	OTB - Sentinel Survey: Aug. Lengths (Liners)	4311	2.728
		OTB - Sentinel Survey: Aug. Ages (Liners)	1124	
NA	Un-sampled	NA	NA	0.356
Total				114.371

Gear Type Abbreviations: OTB = Otter Trawl, SNU = Seine, GN = Gillnet, LL = Longline, LHP = Handline

Length/Weight Coefficients (sexes combined) from Mission T194 (Sept. 2011): a = 0.0000063, b = 3.0818

Table B1d: Age-length keys that were used in the calculation of the 2012 catch-at-age for southern Gulf of St. Lawrence cod.

Key	Fishery	Samples	Total (N)	Landings (t)
1	OTB/SNU - Bycatch: Apr. - Oct. (No Liners)	OTB/SNU - Bycatch: Apr. - Oct. Lengths (No Liners)	1129	17.029
		OTB/SNU - Bycatch: Apr. - Oct. Ages (No Liners)	477	
2	GN/LL/LHP - Bycatch: Apr. - Nov.	GN/LL/LHP - Bycatch: Apr. - Nov. Lengths	573	126.646
		GN/LL/LHP – Bycatch: Apr. - Nov. Ages	373	
3	LL - Sentinel Survey: Jul. – Sept.	LL - Sentinel Survey: Jul. – Sept. Lengths	10833	19.040
		LL - Sentinel Survey: Jul. – Sept. Ages	1322	
4	LL - Sentinel Survey: Oct. – Nov.	LL - Sentinel Survey: Oct. – Nov. Lengths	3148	4.988
		LL - Sentinel Survey: Oct. – Nov. Ages	380	
5	OTB - Sentinel Survey: Aug. (Liners)	OTB - Sentinel Survey: Aug. Lengths (Liners)	3364	2.469
		OTB - Sentinel Survey: Aug. Ages (Liners)	940	
NA	Un-sampled	NA	NA	1.836
Total				172.008

Gear Type Abbreviations: OTB = Otter Trawl, SNU = Seine, GN = Gillnet, LL = Longline, LHP = Handline

Length/Weight Coefficients (sexes combined) from Mission T205 (Sept. 2012): a = 0.0000067, b = 3.0666

Table B1e: Age-length keys that were used in the calculation of the 2013 catch-at-age for southern Gulf of St. Lawrence cod.

Key	Fishery	Samples	Total (N)	Landings (t)
1	OTB/SNU - Bycatch: Apr. – Dec. (No Liners)	OTB/SNU - Bycatch: Apr. – Dec. Lengths (No Liners)	288	9.014
		OTB/SNU - Bycatch: Apr. – Dec. Ages (No Liners)	195	
2	GN/LL/LHP - Bycatch: Apr. - Oct.	GN/LL/LHP - Bycatch: Apr. - Oct. Lengths	1322	81.135
		GN/LL/LHP – Bycatch: Apr. - Oct. Ages	496	
3	LL - Sentinel Survey: Jul. – Nov.	LL - Sentinel Survey: Jul. – Nov. Lengths	12790	19.269
		LL - Sentinel Survey: Jul. – Nov. Ages	1203	
4	OTB - Sentinel Survey: Aug. (Liners)	OTB - Sentinel Survey: Aug. Lengths (Liners)	2716	1.618
		OTB - Sentinel Survey: Aug. Ages (Liners)	789	
NA	Un-sampled	NA	NA	0.264
Total				111.300

Gear Type Abbreviations: OTB = Otter Trawl, SNU = Seine, GN = Gillnet, LL = Longline, LHP = Handline

Length/Weight Coefficients (sexes combined) from Mission T318 (Sept. 2013): a = 0.0000067, b = 3.0721

Table B1f: Age-length keys that were used in the calculation of the 2014 catch-at-age for southern Gulf of St. Lawrence cod.

Key	Fishery	Samples	Total (N)	Landings (t)
1	OTB/SNU - Bycatch: May - Oct. (No Liners)	OTB/SNU - Bycatch: May - Oct. Lengths (No Liners)	1304	22.859
		OTB/SNU - Bycatch: May - Oct. Ages (No Liners)	382	
2	GN/LL/LHP - Bycatch: Apr. - Nov.	GN/LL/LHP - Bycatch: Apr. - Nov. Lengths	699	69.098
		GN/LL/LHP – Bycatch & Sentinel: Apr. - Nov. Ages	1005	
3	LL - Sentinel Survey: Jul. – Nov.	LL - Sentinel Survey: Jul. – Nov. Lengths	6801	14.773
		LL - Sentinel Survey: Jul. – Nov. Ages	940	
4	OTB - Sentinel Survey: Aug. (Liners)	OTB - Sentinel Survey: Aug. Lengths (Liners)	4466	4.133
		OTB - Sentinel Survey: Aug. Ages (Liners)	1288	
NA	Un-sampled	NA	NA	3.607
Total				114.470

Gear Type Abbreviations: OTB = Otter Trawl, SNU = Seine, GN = Gillnet, LL = Longline, LHP = Handline

Length/Weight Coefficients (sexes combined) from Mission T433 (Sept. 2014): a = 0.0000070, b = 3.0606

Table B2a: Landings (numbers) at age by gear in 2009. The age-key numbers correspond with Table 9a (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter						
Age	1 OTB/SNU Comm. (NoL) 2 - 3	2 OTB/SNU Comm. (NoL) 4	3 GN/LL/LHP Comb. 2 - 4	4 LL Sent. 3 - 4	5 OTB Sent. (L) 3	Un-sampled	Total
0	0	0	0	0	0	0	0
1	0	0	0	0	24	0	24
2	0	0	0	2	1,157	0	1,160
3	22	48	0	31	4,176	0	4,277
4	267	917	42	479	3,891	1	5,597
5	940	3,076	301	861	967	4	6,149
6	3,103	3,303	3,931	4,289	1,345	10	15,980
7	2,941	7,947	2,860	2,078	396	13	16,235
8	7,554	5,358	8,093	4,190	701	19	25,915
9	3,117	1,533	4,357	1,984	256	8	11,255
10	2,517	546	4,860	1,653	76	7	9,660
11	418	226	1,549	509	24	2	2,727
12	157	286	1,654	482	8	2	2,588
13	69	18	775	246	4	1	1,112
14	168	17	406	142	2	1	735
15	32	0	86	52	0	0	170
16+	48	0	0	0	0	0	48
Total (all)	21,351	23,275	28,913	16,998	13,026	68	103,631
Total (3+)	21,351	23,275	28,913	16,996	11,845	68	102,448

Table B2b: Landings (numbers) at age by gear in 2010. The age-key numbers correspond with Table 9b (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
1	0	0	0	76	0	76
2	0	0	0	444	0	444
3	0	63	63	749	0	811
4	1,041	692	692	929	0	3,083
5	3,234	2,429	2,429	1,315	1	9,661
6	2,671	2,056	2,056	345	1	8,713
7	4,265	3,829	3,829	474	2	16,154
8	2,160	2,060	2,060	171	1	9,151
9	2,396	2,613	2,613	204	1	11,350
10	958	1,512	1,512	111	1	6,345
11	425	517	517	44	0	2,152
12	0	156	156	2	0	801
13	47	57	57	5	0	245
14	0	24	24	4	0	132
15	0	15	15	0	0	100
16+	0	10	10	0	0	30
Total (all)	17,196	16,031	16,031	4,871	7	69,248
Total (3+)	17,196	16,031	16,031	4,352	7	68,728

Table B2c: Landings (numbers) at age by gear in 2011. The age-key numbers correspond with Table 9c (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). *Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.*

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	0	0	0	0	0	0
1	0	0	0	46	0	46
2	0	0	9	298	0	307
3	0	0	163	1,249	0	1,412
4	34	535	1,697	740	2	3,007
5	1,544	2,673	2,762	957	13	7,948
6	1,825	5,598	2,972	1,031	23	11,448
7	1,554	8,930	1,310	171	33	11,997
8	2,128	10,570	1,372	194	40	14,305
9	2,226	6,407	921	87	27	9,667
10	0	3,842	675	120	12	4,650
11	420	1,261	160	20	5	1,866
12	0	619	79	11	2	710
13	0	212	25	0	1	237
14	0	83	17	0	0	101
15	0	149	0	3	0	152
16+	0	37	0	0	0	37
Total (all)	9,731	40,915	12,161	4,925	158	67,890
Total (3+)	9,731	40,915	12,153	4,581	158	67,537

Table B2d: Landings (numbers) at age by gear in 2012. The age-key numbers correspond with Table 9d (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). *Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.*

	Key - Gear - Source - Quarter						
Age	1 OTB/SNU Comm. (NoL) 2 - 4	3 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3	4 LL Sent. 4	5 OTB Sent. (L) 3	Un-sampled	Total
0	0	0	0	0	1	0	1
1	0	0	0	0	3	0	3
2	0	0	4	0	199	0	203
3	0	65	100	63	1,242	1	1,471
4	24	2,170	654	433	2,334	23	5,639
5	677	4,651	2,517	957	394	57	9,253
6	2,567	15,275	3,322	1,186	450	190	22,991
7	2,476	22,927	2,672	584	391	271	29,321
8	1,128	9,237	1,114	142	58	111	11,789
9	1,093	8,659	1,032	120	87	104	11,094
10	910	5,167	530	89	25	65	6,786
11	704	1,703	418	64	41	26	2,956
12	159	1,287	176	11	6	15	1,656
13	42	168	36	14	1	2	263
14	0	0	24	13	1	0	37
15	0	192	15	0	0	2	209
16+	0	0	0	0	0	0	0
Total (all)	9,780	71,500	12,614	3,677	5,233	868	103,671
Total (3+)	9,780	71,500	12,610	3,677	5,031	868	103,465

Table B2e: Landings (numbers) at age by gear in 2013. The age-key numbers correspond with Table 9e (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	0	0	0	1	0	1
1	0	0	0	96	0	96
2	0	0	0	371	0	371
3	0	0	7	668	0	675
4	16	648	320	651	2	1,635
5	87	2,425	1,375	1,052	6	4,945
6	332	3,684	1,910	341	10	6,276
7	826	4,933	2,694	147	14	8,613
8	1,286	10,061	2,771	98	27	14,243
9	846	8,010	933	36	21	9,846
10	279	6,485	1,141	32	16	7,954
11	210	1,783	432	9	5	2,438
12	429	1,441	437	7	4	2,319
13	199	1,443	176	0	4	1,821
14	32	258	59	1	1	350
15	16	0	9	0	0	25
16+	0	0	0	0	0	0
Total (all)	4,557	41,169	12,263	3,510	108	61,607
Total (3+)	4,557	41,169	12,263	3,042	108	61,139

Table B2f: Landings (numbers) at age by gear in 2014. The age-key numbers correspond with Table 9f (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	0	0	0	0	0	0
1	0	0	0	17	0	17
2	0	0	0	300	0	300
3	0	103	14	1,566	3	1,686
4	0	685	363	2,995	22	4,065
5	1,304	4,945	2,031	1,670	197	10,147
6	2,055	5,082	1,912	877	225	10,151
7	2,060	5,360	1,566	220	234	9,439
8	2,275	4,799	1,267	122	223	8,686
9	2,074	4,761	993	125	215	8,168
10	428	1,651	282	27	66	2,453
11	302	2,770	489	22	97	3,680
12	229	1,025	176	3	40	1,473
13	235	1,120	136	2	43	1,536
14	42	235	47	0	9	333
15	0	483	12	1	15	512
16+	0	0	0	0	0	0
Total (all)	11,003	33,019	9,289	7,948	1,387	62,645
Total (3+)	11,003	33,019	9,289	7,630	1,387	62,328

Table B3a: Mean weight (kg) at age by gear in 2009. The age-key numbers correspond with Table 9a (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter						
Age	1 OTB/SNU Comm. (NoL) 2 - 3	2 OTB/SNU Comm. (NoL) 4	3 GN/LL/LHP Comb. 2 - 4	4 LL Sent. 3 - 4	5 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-	-
1	-	-	-	-	0.03	-	0.03
2	-	-	-	0.18	0.14	-	0.14
3	0.16	0.34	-	0.37	0.25	-	0.25
4	0.51	0.61	0.68	0.57	0.35	-	0.42
5	0.87	0.77	1.04	0.78	0.52	-	0.76
6	0.92	0.94	1.28	1.08	0.80	-	1.05
7	1.25	1.09	1.41	1.24	1.00	-	1.19
8	1.54	1.26	1.87	1.65	1.26	-	1.60
9	2.13	1.59	2.08	1.74	1.53	-	1.96
10	2.09	1.89	2.46	2.22	1.66	-	2.28
11	2.32	1.99	2.64	2.25	1.98	-	2.46
12	2.83	1.85	2.79	2.28	1.32	-	2.59
13	4.91	1.83	2.75	2.63	2.00	-	2.84
14	2.52	1.74	3.20	2.92	2.12	-	2.95
15	2.79	-	2.50	2.47	-	-	2.55
16+	3.14	-	-	-	-	-	3.14
Weighted average (all)	1.57	1.12	2.00	1.51	0.46	-	1.44
Weighted average (3+)	1.57	1.12	2.00	1.51	0.49	-	1.45

Table B3b: Mean weight (kg) at age by gear in 2010. The age-key numbers correspond with Table 9b (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-
1	-	-	-	0.02	-	0.02
2	-	-	-	0.05	-	0.05
3	-	-	0.37	0.28	-	0.29
4	0.60	0.81	0.67	0.42	-	0.59
5	0.76	0.96	0.87	0.61	-	0.82
6	1.15	1.28	1.17	0.87	-	1.20
7	1.21	1.55	1.41	1.09	-	1.41
8	1.59	1.80	1.59	1.34	-	1.69
9	1.77	2.04	1.79	1.57	-	1.92
10	1.90	2.32	1.94	1.68	-	2.16
11	1.95	2.16	1.92	1.73	-	2.05
12	-	3.69	2.37	2.04	-	3.43
13	4.93	2.60	2.11	2.16	-	2.92
14	-	3.29	2.76	1.11	-	3.13
15	-	3.68	3.61	-	-	3.67
16+	-	2.15	2.15	-	-	2.15
Weighted average (all)	1.27	1.77	1.43	0.63	-	1.49
Weighted average (3+)	1.27	1.77	1.43	0.70	-	1.50

Table B3c: Mean weight (kg) at age by gear in 2011. The age-key numbers correspond with Table 9c (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-
1	-	-	-	0.02	-	0.02
2	-	-	0.09	0.09	-	0.09
3	-	-	0.51	0.16	-	0.20
4	0.96	0.95	0.76	0.37	-	0.70
5	1.20	1.25	1.02	0.55	-	1.07
6	1.14	1.37	1.27	0.80	-	1.25
7	1.34	1.68	1.63	1.19	-	1.62
8	1.80	2.05	1.68	1.40	-	1.97
9	1.86	2.44	1.71	1.48	-	2.23
10	-	2.54	2.12	1.76	-	2.46
11	2.68	2.64	2.44	1.77	-	2.62
12	-	3.23	1.55	1.81	-	3.02
13	-	2.39	2.28	-	-	2.38
14	-	1.63	2.50	-	-	1.78
15	-	2.50	-	2.12	-	2.49
16+	-	7.50	-	-	-	7.50
Weighted average (all)	1.55	1.96	1.32	0.55	-	1.68
Weighted average (3+)	1.55	1.96	1.32	0.59	-	1.69

Table B3d: Mean weight (kg) at age by gear in 2012. The age-key numbers correspond with Table 9d (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter						
Age	1 OTB/SNU Comm. (NoL) 2 - 4	3 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3	4 LL Sent. 4	5 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	0.01	-	0.01
1	-	-	-	-	0.02	-	0.02
2	-	-	0.24	-	0.10	-	0.10
3	-	0.79	0.52	0.46	0.21	-	0.27
4	0.56	0.99	0.72	0.68	0.31	-	0.65
5	1.00	1.23	1.06	1.09	0.63	-	1.13
6	1.43	1.61	1.37	1.43	0.88	-	1.53
7	1.54	1.57	1.60	1.58	1.14	-	1.56
8	1.98	1.97	1.86	2.03	1.60	-	1.96
9	2.26	2.08	2.03	2.18	1.54	-	2.09
10	2.35	2.48	2.45	2.61	1.96	-	2.46
11	2.21	3.20	2.29	2.26	2.13	-	2.80
12	2.37	2.28	2.13	1.90	2.54	-	2.27
13	2.55	2.46	2.66	2.47	3.05	-	2.51
14	-	-	2.38	1.23	3.05	-	2.01
15	-	2.67	2.68	-	-	-	2.67
16+	-	-	3.19	-	-	-	3.19
Weighted average (all)	1.74	1.77	1.51	1.36	0.47	-	1.66
Weighted average (3+)	1.74	1.77	1.51	1.36	0.49	-	1.66

Table B3e: Mean weight (kg) at age by gear in 2013. The age-key numbers correspond with Table 9e (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	0.00	-	0.00
1	-	-	-	0.03	-	0.03
2	-	-	-	0.09	-	0.09
3	-	-	0.71	0.22	-	0.23
4	0.37	0.87	0.82	0.36	-	0.65
5	0.60	0.93	0.88	0.52	-	0.82
6	1.11	1.11	1.18	0.68	-	1.11
7	1.34	1.40	1.42	0.88	-	1.39
8	1.73	1.87	1.69	1.33	-	1.82
9	2.12	2.11	1.94	1.60	-	2.09
10	2.72	2.57	2.13	1.89	-	2.51
11	2.75	2.75	2.32	2.33	-	2.67
12	3.04	3.41	2.59	2.28	-	3.18
13	3.19	2.88	2.72	0.00	-	2.90
14	4.32	3.73	2.55	4.40	-	3.58
15	3.15	-	2.63	-	-	2.96
16+	-	-	-	-	-	-
Weighted average (all)	1.98	1.97	1.57	0.46	-	1.81
Weighted average (3+)	1.98	1.97	1.57	0.52	-	1.82

Table B3f: Mean weight (kg) at age by gear in 2014. The age-key numbers correspond with Table 9f (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). *Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.*

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-
1	-	-	-	0.02	-	0.02
2	-	-	-	0.15	-	0.15
3	-	0.41	0.39	0.25	-	0.26
4	-	0.94	0.82	0.39	-	0.52
5	1.34	1.20	1.13	0.61	-	1.10
6	1.53	1.34	1.20	0.79	-	1.30
7	2.10	1.81	1.64	1.13	-	1.83
8	2.27	1.93	1.78	1.45	-	1.99
9	2.46	2.39	2.08	1.90	-	2.36
10	2.86	3.05	2.32	2.24	-	2.92
11	2.63	3.26	2.47	2.57	-	3.10
12	3.00	2.93	2.75	2.56	-	2.92
13	2.61	4.04	3.25	4.42	-	3.74
14	1.75	2.95	2.69	-	-	2.75
15	-	6.35	4.98	4.86	-	6.31
16+	-	-	-	-	-	-
Weighted average (all)	2.08	2.09	1.59	0.52	-	1.81
Weighted average (3+)	2.08	2.09	1.59	0.54	-	1.82

Table B4a: Mean length (cm) at age by gear in 2009. The age-key numbers correspond with Table 9a (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter						
Age	1 OTB/SNU Comm. (NoL) 2 - 3	2 OTB/SNU Comm. (NoL) 4	3 GN/LL/LHP Comb. 2 - 4	4 LL Sent. 3 - 4	5 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-	-
1	-	-	-	-	15.0	-	15.0
2	-	-	-	27.2	24.6	-	24.6
3	26.0	33.3	-	34.3	29.8	-	29.9
4	37.4	40.5	41.9	39.4	33.3	-	35.3
5	45.7	43.8	48.4	43.7	38.2	-	43.4
6	46.5	46.9	52.0	48.9	44.3	-	48.4
7	51.4	49.2	53.6	51.2	47.7	-	50.6
8	54.9	51.6	58.7	56.3	51.5	-	55.6
9	61.1	55.6	60.8	57.3	54.8	-	59.4
10	60.9	58.8	64.2	61.9	56.5	-	62.6
11	62.2	59.9	65.9	62.6	59.6	-	64.2
12	67.9	58.6	66.8	62.4	52.0	-	65.1
13	81.5	59.0	67.0	65.9	60.7	-	67.5
14	65.5	58.0	70.3	68.3	62.0	-	68.5
15	68.0	-	64.1	63.8	-	-	64.7
16+	70.7	-	-	-	-	-	70.7
Weighted average (all)	54.6	49.2	59.7	53.9	34.9	-	52.2
Weighted average (3+)	54.6	49.2	59.7	53.9	36.0	-	52.5

Table B4b: Mean length (cm) at age by gear in 2010. The age-key numbers correspond with Table 9b (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-
1	-	-	-	13.5	-	13.5
2	-	-	-	17.4	-	17.4
3	-	-	34.6	31.5	-	31.8
4	40.6	44.9	41.9	35.9	-	40.1
5	43.8	47.4	45.8	40.9	-	44.9
6	50.1	51.9	50.4	45.8	-	50.8
7	50.7	55.2	53.5	49.1	-	53.4
8	55.4	57.9	55.6	52.6	-	56.7
9	57.1	60.2	57.9	55.1	-	58.9
10	58.3	62.5	59.2	56.8	-	61.0
11	58.8	61.3	59.1	57.4	-	60.2
12	-	71.9	62.5	61.0	-	70.0
13	80.3	65.3	61.3	62.1	-	67.2
14	-	70.7	66.5	50.0	-	69.3
15	-	73.8	73.4	-	-	73.7
16+	-	62.0	62.0	-	-	62.0
Weighted average (all)	50.9	57.1	53.2	38.6	-	53.3
Weighted average (3+)	50.9	57.1	53.2	41.2	-	53.6

Table B4c: Mean length (cm) at age by gear in 2011. The age-key numbers correspond with Table 9c (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-
1	-	-	-	14.4	-	14.4
2	-	-	22.0	21.4	-	21.4
3	-	-	38.9	26.7	-	28.1
4	48.0	47.5	44.2	34.8	-	42.5
5	51.0	51.7	48.5	39.6	-	49.0
6	50.4	53.3	52.0	44.8	-	51.7
7	53.1	57.0	56.4	50.9	-	56.3
8	58.1	60.5	56.9	53.5	-	59.7
9	58.8	64.0	57.3	54.7	-	62.1
10	-	64.5	61.4	57.8	-	63.9
11	66.8	65.6	64.2	58.2	-	65.6
12	-	69.9	55.9	58.8	-	68.1
13	-	64.1	62.0	-	-	63.9
14	-	57.0	64.7	-	-	58.3
15	-	65.4	-	62.0	-	65.3
16+	-	93.5	-	-	-	93.5
Weighted average (all)	55.2	59.3	52.1	37.1	-	55.8
Weighted average (3+)	55.2	59.3	52.1	38.4	-	56.0

Table B4d: Mean length (cm) at age by gear in 2012. The age-key numbers correspond with Table 9d (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter						
Age	1 OTB/SNU Comm. (NoL) 2 - 4	3 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3	4 LL Sent. 4	5 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	10.0	-	10.0
1	-	-	-	-	13.5	-	13.5
2	-	-	30.4	-	22.2	-	22.3
3	-	45.0	39.1	37.5	28.7	-	30.5
4	40.1	48.0	43.4	42.6	32.7	-	40.6
5	48.3	51.6	49.1	49.6	41.1	-	50.0
6	54.1	56.2	53.3	54.0	46.2	-	55.2
7	55.3	56.0	56.1	55.8	50.4	-	55.8
8	60.0	60.1	58.8	60.4	56.2	-	59.9
9	62.7	61.3	60.3	62.3	55.5	-	61.3
10	63.4	63.9	63.9	65.1	59.4	-	63.8
11	62.3	69.5	62.8	62.6	61.4	-	66.6
12	64.2	63.5	61.5	60.0	64.5	-	63.3
13	65.8	65.1	66.1	65.3	70.0	-	65.4
14	-	-	63.4	52.0	70.0	-	59.7
15	-	67.0	66.5	-	-	-	67.0
16+	-	-	71.0	-	-	-	71.0
Weighted average (all)	57.3	57.7	54.4	52.5	35.5	-	56.0
Weighted average (3+)	57.3	57.7	54.4	52.5	36.1	-	56.0

Table B4e: Mean length (cm) at age by gear in 2013. The age-key numbers correspond with Table 9e (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	6.1	-	6.1
1	-	-	-	15.0	-	15.0
2	-	-	-	21.2	-	21.2
3	-	-	43.0	29.3	-	29.5
4	35.0	45.5	44.9	34.3	-	40.8
5	40.6	46.4	45.6	38.6	-	44.4
6	49.3	49.2	50.4	42.1	-	49.2
7	52.6	53.0	53.5	45.9	-	53.0
8	56.8	58.2	56.6	52.2	-	57.7
9	60.5	60.7	59.2	55.5	-	60.5
10	65.8	64.5	60.8	58.4	-	64.0
11	66.0	66.2	62.7	61.9	-	65.5
12	68.0	71.3	64.8	62.3	-	69.5
13	69.0	67.4	66.0	-	-	67.4
14	77.5	73.7	64.6	78.0	-	72.5
15	70.0	-	66.0	-	-	68.5
16+	-	-	-	-	-	-
Weighted average (all)	58.5	58.6	54.7	35.0	-	56.5
Weighted average (3+)	58.5	58.6	54.7	37.4	-	56.7

Table B4f: Mean length (cm) at age by gear in 2014. The age-key numbers correspond with Table 9f (Comm. = Commercial, Sent. = Sentinel, Comb. = Commercial & Sentinel, L=Liner, NoL=No Liner). Quarter abbreviations are: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December.

	Key - Gear - Source - Quarter					
Age	1 OTB/SNU Comm. (NoL) 2 - 4	2 GN/LL/LHP Comb. 2 - 4	3 LL Sent. 3 - 4	4 OTB Sent. (L) 3	Un-sampled	Total
0	-	-	-	-	-	-
1	-	-	-	12.0	-	12.0
2	-	-	-	25.7	-	25.7
3	-	36.0	35.4	30.4	-	30.8
4	-	46.9	44.5	35.2	-	38.0
5	52.8	50.7	49.8	40.7	-	49.1
6	55.2	52.4	50.6	44.2	-	51.9
7	60.9	57.9	56.1	49.5	-	58.0
8	62.4	59.3	57.8	54.0	-	59.8
9	63.9	63.2	60.7	57.6	-	63.0
10	67.4	67.9	62.6	62.2	-	67.1
11	65.2	69.3	63.9	64.3	-	68.2
12	68.3	68.0	66.5	65.4	-	67.9
13	65.4	75.3	70.0	78.4	-	73.3
14	58.0	68.2	66.2	-	-	66.6
15	-	87.8	80.8	80.9	-	87.6
16+	-	-	-	-	-	-
Weighted average (all)	60.3	59.5	54.9	37.2	-	56.1
Weighted average (3+)	60.3	59.5	54.9	37.7	-	56.2

APPENDIX C: EFFECT OF FITTING TO PROPORTIONS AT AGE IN THE FISHERY CATCH IN THE 1950S AND 1960S ON ESTIMATES BY STATISTICAL CATCH-AT-AGE MODELS

The estimate of initial *M* for ages 9 years and older by the SCA model (0.35) was considerably higher than the VPA estimate (0.23) and the estimates by independent studies using data from the 1960s and 1970s (0.1 – 0.2). Due to time constraints, this was investigated further subsequent to the review meeting for the 2015 sGSL cod assessment. The age composition of the fishery catch in the 1950s is based on little sampling and is considered highly uncertain (J.J. Maguire, pers. comm.) The possibility that the SCA estimate for initial 9+ *M* was strongly influenced by fitting to the proportions at age in the fishery catch in early years was examined. Estimates were compared between three SCA models:

1. SCA1: the SCA model used in the assessment, which fits to the proportions at age in the fishery catches from 1950 to 2014.
2. SCA2: like the SCA model used in the assessment, except fitting to the proportions at age in the fishery catches begins in 1960.
3. SCA3: like the SCA model used in the assessment, except the model begins in 1971, the first year with fishery-independent biomass indices and age compositions.

Estimates are compared between these three models in Figures C1 and C2. VPA estimates are also included for comparison. Initial 9+ *M* decreases from 0.35 to 0.30 if fitting to the proportions-at-age in the fishery catch begins in 1960. The estimate declines further to 0.26 if the SCA model begins in 1971, close to the VPA estimate of 0.23 and the earlier estimates of 0.1 – 0.2. Thus, fitting to the uncertain proportions-at-age in the fishery catch in early years does have a substantial effect on the SCA estimate for initial *M* of cod aged 9 years and older. However, the estimates converge over time, with differences negligible since the mid-1990s. Effects of fitting to the proportions-at-age in the fishery catch in the early years are negligible for *M* of cod aged 5-8 years (Fig. C1), average *F* for ages 5-8 and 9+ (Fig. C2) and, except in the 1950s, for 5+ biomass (Fig. C1).

In conclusion, the SCA estimate for initial 9+ *M* is influenced by whether the model fits to the proportions at age in the fishery catch in the early years, when observation error in these proportions is considered to be high. If these early years are included in the fitting, the estimate is higher than expected based on the level of *M* considered normal for adult cod (about 0.2), the independent estimates for the 1960s -1970s period (Dickie 1963, Beverton 1965, Myers and Doyle 1983) and the estimate from VPA (Fig. C1). However, estimates from the different models converge to similar values in recent years, so conclusions about current status are not affected. A solution would be to begin the SCA model in 1971. However, it is important to include the 1950s and 1960s in the model to retain a longer historical perspective. Further work on this issue is needed.

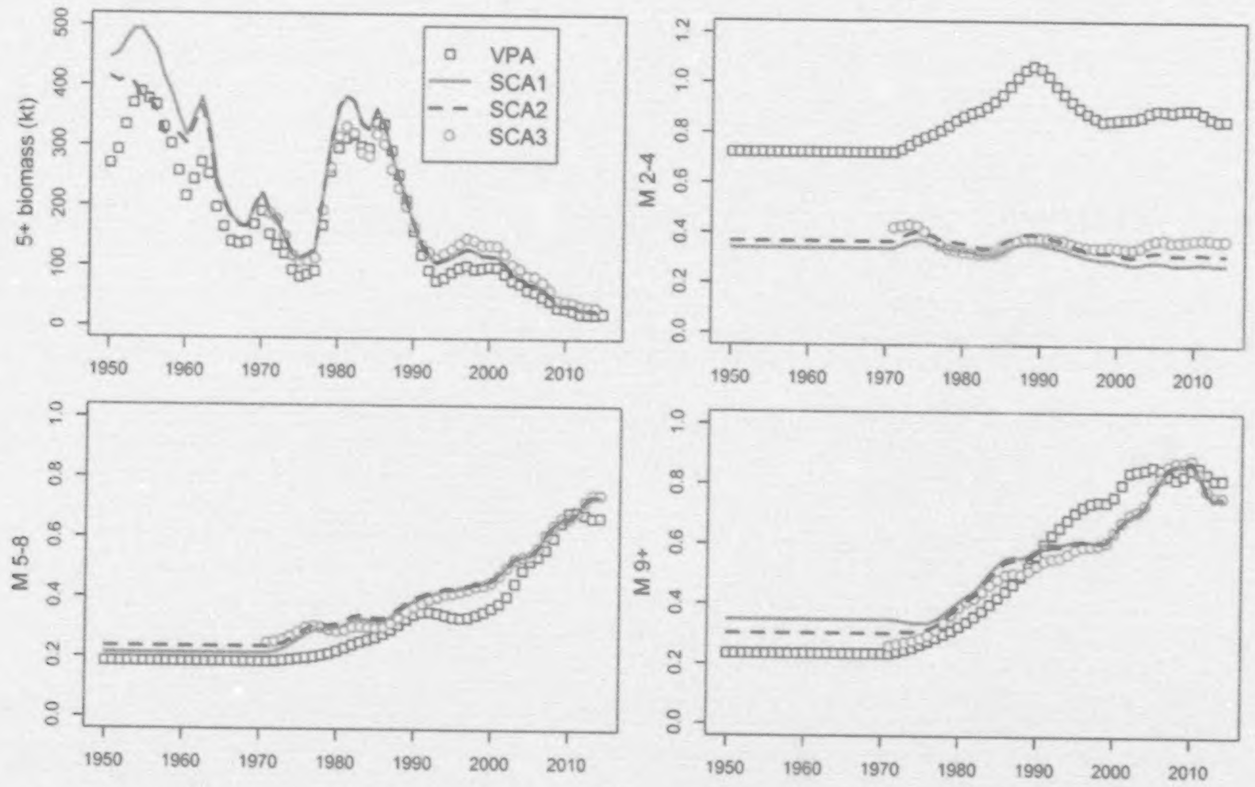


Figure C: Estimates of 5+ biomass and M for ages 2-4, 5-8 and 9+ years from the models presented at the assessment review (VPA and SCA1) and additional SCA models that either start in 1950 but begin fitting the proportions at age in the fishery catch in 1960 (SCA2) or begin in 1971 (SCA3).

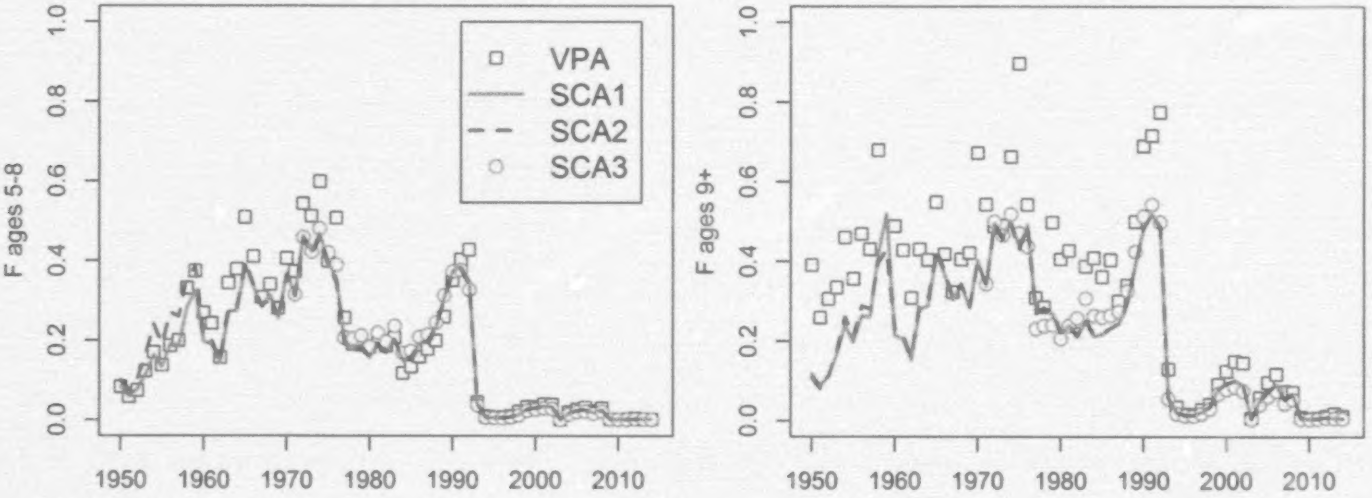


Figure C2: Estimates of F for ages 5-8 and 9+ years from the models presented at the assessment review (VPA and SCA1) and additional SCA models that either start in 1950 but begin fitting the proportions at age in the fishery catch in 1960 (SCA2) or begin in 1971 (SCA3).